Science Library

DEC 21 1944

Volume 34 *Number 12*

Phytopathology

AN INTERNATIONAL JOURNAL

December 1944

Official Organ of

The American Phytopathological Society

$6.25 per year, Canada $6.00 per year, United States and dependencies $6.50 per year, elsewhere

Office of Publication

Corner North Queen Street and McGovern Avenue, Lancaster, Pennsylvania

Entered at the postoffice in Lancaster, Pennsylvania, as second-class matter

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PHYTOPATHOLOGY

An International Journal
Official Organ of The American Phytopathological Society

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ABSTRACTS OF PAPERS ACCEPTED FOR PRESENTATION AT THE THIRTY-SIXTH ANNUAL MEETING OF THE SOCIETY, CINCINNATI, OHIO, DECEMBER 9 TO 11, 1944

Physiological Maturity in Relation to Alternaria Blight in the Tomato. BARRATT, R. W. AND M. C. RICHARDS. Investigations show that all tomato varieties and breeding lines now available are susceptible to *Alternaria solani* when tested under conditions favorable for infection. Experiments over a three-year period to investigate differences in field defoliation show that the extent of defoliation of a tomato plant from *Alternaria solani* is related to the physiological maturity of the plant. Fruit to leaf quotient and period of yield are two of the major factors causing physiological maturity of the tomato. A relationship, which can be shown graphically, exists between the period of yield and period of defoliation regardless of variety. Early varieties, or early plantings of a variety, defoliate early because their periods of yield are early. The fruit load of a plant, as expressed by the fruit to leaf quotient, is correlated directly with defoliation, as shown in an experiment involving 16 varieties having a wide range in fruit load. The change in fruit to leaf quotient was followed during the season on four varieties by weekly samples. The data show that this quotient bears a relationship to the degree of defoliation in each variety. This relationship has been shown graphically.

The Use of Eradicant and Blossom Sprays on Sour Cherry in the Control of Brown-rot Blossom and Spur Blight Incited by Sclerotinia laxa Ader. and Ruhl. CALAVAN, E. C. Brown-rot blossom and spur blight of Early Richmond cherries has been controlled effectively in experiments in Door County, Wisconsin, during the past 2 years by the application shortly before budbreak of a copper-lime-monocalcium arsenite and fish oil, 3-2-2-(1½ pints fish oil)-50 eradicant spray, supplemented in early bloom by a protectant spray of Bordeaux mixture, 3-4-50. During the wet spring of 1943 this 2-spray program reduced the amount of total spurs blighted to 0.5 per cent, whereas check trees had 52.7 per cent spurs killed. Less satisfactory control was obtained by the use of either the dormant or the blossom spray alone. Indicated reductions in percentages of total spurs blighted were: for trees receiving the dormant spray only, 97.5; the blossom spray only, 82.1; and both sprays, 99.1. In 1944 the absence of infection periods until most petals had fallen resulted in a small amount, 2.8 per cent, of spurs blighted on check trees. Under such conditions the disease was checked 50 per cent by the dormant spray alone, 60 per cent by the blossom spray alone, and 92 per cent by the application of both sprays.

Wetwood of Elm in Illinois. CARTER, J. C. Wetwood of elm, under investigation in Illinois since 1939, has been shown by inoculation trials to be caused by an undescribed species of *Erwinia*. This bacterium has been derived consistently by cultural methods from the diseased trees studied. It produces gas by fermentation in the infected wood, with the development of abnormally high pressure in the trunk. The fermentation is accompanied by an accumulation of sap in abnormal amounts in the infected wood. The gas pressure, which may reach 60 lb. per square inch forces this sap out through branch cuts, crotch cracks, and other injuries, and produces what is commonly called flux. Sap in affected tissues is toxic; it causes foliage to wilt when it moves into the twigs, and produces a gray brown internal streaking in the current wood of branches through which it moves. Wilting and streaking can be confused with Verticillium wilt symptoms. Gas produced by fermentation in naturally infected trees contains approximately 46 per cent methane, 34 per cent nitrogen, 14 per cent carbon dioxide, 5 per cent oxygen, and 1 per cent hydrogen.

Chemical Treatments in Tobacco Seedbeds. CHAMBERLAIN, DONALD W. Better control measures are being sought for blackfire, wildfire, and damping-off in tobacco seedbeds. Experiments were continued at the Wisconsin Station in 1943 and 1944 with a number of different chemicals. Bordeaux mixture (3–4–50) has continued to give the best results, controlling both wildfire and damping-off 95–99 per cent. Home-mixed Bordeaux generally has given better control of wildfire than did the two popular brands of commercially prepared Bordeaux tested, although the latter satisfactorily controlled damping-off. Weekly treatments, beginning before the plants were above ground, were more effective than less frequent applications. Yellow cuprocide (1¾ lb.–100 gal.) controlled damping-off when applied as a weekly plant treatment or when mixed dry with sand (¾ lb.–100 lb. sand) and spread over the soil surface. Soil treatments, using Bordeaux powder, cuprous oxide, and Fermate, mixed dry into the soil before seeding, generally were unsatisfactory. Fermate, when applied before emergence of the plants, reduced stands in the seedbed.

A Brown Leaf Spot on Bromus inermis Leyss. caused by Pyrenophora bromi (Died.) Drechsler. CHAMBERLAIN, DONALD W., AND J. LEWIS ALLISON. *Pyrenophora bromi* causes a severe brown leaf spot on smooth brome grass in Wisconsin. The disease appears

early in the spring and develops best during moist, cool weather. Initial spring infection is by ascospores matured in early spring in perithecia formed on leaf blades of the host the previous summer. Conidia of the imperfect, or *Helminthosporium bromi*, stage of the fungus are produced sparsely during spring and summer but do not survive the winter and are the least important stage in the life cycle of the fungus. Optimum temperature for ascospore germination is 20° C., and for conidia 28° C. Perithecia bearing mature asci were produced in culture on potato-dextrose agar with either mono-conidial or mono-ascosporic isolates when incubated at 10° C. for 3 months. Inbred lines of smooth brome differ markedly in reaction to this leaf spot at Madison, indicating that selection and breeding offer a method of control. (Cooperative investigations between the Division of Forage Crops and Diseases, U. S. Department of Agriculture and the Wisconsin Agricultural Experiment Station.)

A Lethal Virus of Guar (Cyamopsis psoraloides DC.). CHESTER, K. STARR, AND W. E. COOPER. A necrotic, lethal virus disease was found causing an estimated 75 per cent loss in an experimental field of guar in Oklahoma. Symptoms appear in 6 to 14 days and comprise vein-clearing, sometimes a faint oak-leaf pattern, rolling, wilting, early stipple necrosis, and abscission of young leaves, terminal necrosis, necrotic stem lesions, yellowing and abscission of older leaves, marked stunting of growth, and ultimate death. Occasional plants show abatement of symptoms, following non-lethal necrosis, with mottling, leaf distortion, and stunting. In beans the virus causes systemic necrosis, but it differs from bean virus 4 in that it infects cowpea, soybean, mung bean, and petunia, and from tobacco ring-spot virus in not infecting *Nicotiana glutinosa* and in the type of symptoms produced on *N. tabacum* and petunia. The virus is transmissible mechanically, although not with perfect regularity. It is not destroyed by field temperatures of 42°–45° C. during many days, but the disease becomes masked in hot weather, and in the fall there is a spectacular return of symptoms. Natural infection of 0.1 per cent increases to 100 per cent in a few weeks.

Fusarium Seed-piece Decay of Potatoes. CUNNINGHAM, H. S. Many potato growers on Long Island have sustained serious losses because of seed-piece decay caused by *Fusarium*. Preliminary work indicated that the trouble was confined to seed stock obtained from one section and also, possibly, to one species of *Fusarium*. In 1944 seed-piece decay was found in lots of seed stock from two large seed-producing areas, and it now seems certain that two or more species of *Fusarium* can cause this trouble. The usual recommendation of curing seed pieces at high temperature and high humidity provides ideal conditions for growth of these Fusaria. Under such conditions the seed pieces can become 100 per cent infected and worthless for planting purposes. Seed treatment has been effective in reducing the number of infected seed pieces.

Effect of Nutrient Levels and Temperature on the Development of Puccinia graminis tritici. DARLEY, ELLIS F., AND HELEN HART. In wheat seedlings grown at low nutrient levels and inoculated with *Puccinia graminis tritici* a marked chlorosis accompanied uredia, sporulation was poor, and infection types were relatively low. At high nutrient levels there was almost no chlorosis, sporulation was good, and infection types were relatively high. In adult plants, a high nutrient level delayed maturity 1 to 3 weeks but scarcely affected reaction to stem rust. Mycelial development and sporulation in seedlings were best at 85° F., and poorest at 65° F. Both seedlings and adult plants of one of the Kenya wheats were susceptible to several races of stem rust at 85° F., but were resistant at 72° and 65° F. Newthatch seedlings were flecked by race 17 at 85° F. but seemed immune at 72° and 65° F.

Preliminary Report on a Potato Disease Closely Resembling Fusarium Wilt. DARLING, H. M. AND R. H. LARSON. During the past two years a striking and unusual potato disease has been under observation in Wisconsin. The first symptoms appear during the first part of July as an inward rolling and leathery texture of the lower leaves, followed by chlorosis. Early affected plants become rigid, most of the leaves roll inward, often turn brown, and die prematurely. Severe vascular browning of the lower stem may extend to the third node. Vascular browning of the roots and stolons is common. Tuber set on infected plants does not appear to be affected. A few tubers in a diseased hill become dull and abnormally soft and flabby, while others remain firm and bright. Axillary aerial tubers, tuber and stem necroses, excessive pigmentation, and rosetting were not observed. It does not appear, however, that the last two growing seasons have been such as to cause atypical symptoms of those wilt-producing Fusaria described in the literature.

Growth and Overwintering of Xanthomonas vesicatoria in Association with Wheat Roots. DIACHUN, STEPHEN, AND W. D. VALLEAU. Previous reports from this laboratory have demonstrated that *B. tabacum* and *B. angulatum* can form colonies on wheat roots, and can overwinter in soil, apparently in association with roots. In an extension of these studies *Xanthomonas vesicatoria, X. phascoli* var. *sojense,* and *Bacterium medicaginis* var.

phaseolicola were found to form colonies on the surfaces of roots of wheat seedlings, and to a lesser extent on tomato, bean, and soybean roots. Also, *X. vesicatoria* was recovered from the roots of wheat plants growing out of doors in unsterilized soil infested with the organism. The soil was inoculated November 10, 1943. The bacteria were recovered in each of 5 trials between December 13, 1943, and March 14, 1944, but not on April 14. Individual plants were dug, the roots were washed in running tap water, crushed in water, and poured on the lower surface of water-soaked tomato leaves. Presence of the bacteria on the roots was revealed by development of leaf spots on the inoculated leaves. *X. phaseoli* var. *sojense* and *B. medicaginis* var. *phaseolicola* were not recovered during this period from roots of similar wheat plants growing in soil inoculated with these organisms.

Soil Treatment with Sodium Selenate for Control of Foliar Nematode of Chrysanthemums. DIMOCK, A. W. Excellent control of the foliar nematode disease of chrysanthemums was obtained by treating the soil with water solutions of sodium selenate. Six healthy cuttings, variety Yellow Fellow, were planted in each of 24 flats of composted soil on May 28, 1944. Twelve flats were given 25 parts sodium selenate per million of soil on June 8, and 6 of these were given 25 ppm. again on June 16. No further treatments were made. Inoculum, consisting of fragmented infected leaves, was distributed over the surfaces of all treated flats and 6 of the untreated flats immediately after making the June 8 treatment. All flats were watered overhead frequently until removed for examination on September 25. Superficial examination showed heavy and unmistakable infection in all 36 plants of the untreated, inoculated series, in only one plant of the 25 ppm. series, and in none of the 50 ppm. series. Infection had obviously spread to 3 flats of the untreated, uninoculated series. All plants of the 50 ppm. series showed considerable selenium injury of the lower foliage and some stunting, but the plants of the 25 ppm. series showed only slight selenium injury and little or no stunting.

Light, Drought, and Heat as Factors in Cotton Boll-Shedding. DUNLAP, A. A. The shedding of immature cotton bolls has long been recognized as a menace in obtaining maximum yields. Experimentally, shedding has been most readily caused by subjecting plants in actively-fruiting stages to periods (2 to 5 days) of low light intensities (50 to 2500 foot candles). Continuous wilting of plants for a few days also has resulted in excessive shedding, although frequent brief periods of wilting have not been effective. In addition, high daily temperatures above 100° F. have caused high rates of shedding. Association of these factors with low rates of photosynthesis has been ascertained by chemical analyses of leaf tissues. Certain varieties of upland cotton have shown considerable resistance to inadequate light effects, which predispose the plant to shed its fruiting forms.

Comparative Studies of Basidiospore Cultures of Rhizoctonia solani. EXNER, BEATRICE, AND S. J. P. CHILTON. It has been possible with certain tissue cultures of *Rhizoctonia solani* to produce basidial mats under relatively controlled conditions. The fungus is grown in flasks of potato-dextrose broth for about ten days, after which the mycelial mat is washed in distilled water and placed in a small Erlenmeyer flask with rooted cuttings of Alligator weed (*Alternanthera philoxeroides*). Sufficient water is added to maintain the cuttings and the humidity. Basidial mats form on the surface of the stems. Single basidiospore cultures isolated from these mats differ in rate of growth, size and shape of sclerotia, and in color. As many as 30 distinct cultural strains have been isolated from a basidial mat formed by one of these cultures. In limited tests no basidial mats were formed by single basidiospore cultures growing alone or paired in various combinations. These results indicate that the fusion nucleus presumably forms in the basidial stage of *R. solani*, is heterozygous, and that new strains can arise by segregation.

Temperature Inhibition of Storage Development of Net Necrosis and "Stem-end Browning" of Maine Potatoes of the Green Mountain Variety. FOLSOM, DONALD. In Northeastern Maine where Green Mountain potatoes are harvested as soon as possible after maturity, net necrosis (from current-season leaf-roll infection) and "stem-end browning" (cause undetermined) normally develop only in storage. Their development is maximum and most rapid at about 45° to 50° F., at which temperature the peak usually is reached in 60 to 90 days, and is not influenced by relative humidity. The optimum and maximum temperatures are somewhat higher for stem-end browning than for net necrosis. Development does not occur or is greatly reduced, even at optimum temperatures, if the storage temperature is first held for 60 days at 70° F., which is above the temperature range, or for 30 to 60 days at 32° to 36° F., which is near the lower end of the temperature range. This effect decreases progressively with shorter periods of exposures to the extreme temperatures and as the temperatures approach optimum for necrosis.

Potato Resistance to Leaf Roll. FOLSOM, DONALD, AND F. J. STEVENSON. In southwestern Maine, with leaf-roll plants of a commercial variety always in adjacent rows, 70 to 90 per cent of 8,586 seedlings tested in the six years from 1938 to 1943 acquired the

disease in one year, as evidenced by symptoms appearing the following year. Similarly exposed healthy plants of the Chippewa and Green Mountain varieties had respectively, 85 and 50 per cent leaf roll on the average per year. Among the 5,518 seedlings introduced from 1938 to 1941 inclusive, only 21 are left, most of which are from the cross Imperia × Earlaine. These 21 have remained practically free of leaf roll. Leaf-roll infection has been the basis for elimination of most of the others. When several of these apparently resistant seedlings were crossed with good commercial varieties, the resulting seedlings generally were more vigorous than the resistant parent, and considering all crosses for which they were used, only 55 per cent of these contracted leaf roll in the first year of exposure. It seems possible to produce commercially valuable new seedlings resistant enough to leaf roll to avoid severe field spread of the disease.

Control of Cabbage Mildew by Means of Benzene Vapor. FOSTER, H. H., AND J. A. PINCKARD. The production of cabbage seedlings for the early crop in Mississippi frequently is limited by *Peronospora parasitica*. Benzene vapor applied to experimental seedbeds resulted in an average of 256 seedlings per square foot; untreated beds produced an average of 158 plants. The average length of treated seedlings was 4.9 inches and of the untreated, 2.8 inches. Losses from undetermined root and stem rots continued to develop in the untreated plants. The most effective treatment consisted of nightly applications of 50 cc. of benzene applied to each cotton ball weighing 15 grams and suspended in the seedbed, one ball per 2 square yards. Wet seedbed covers having a thread count of 48 by 44 were used. Treatments were begun 36 hours after inoculation and continued from November 24 to December 28. Significantly effective control was obtained also after mildew appeared in farm beds using 50 cc. of benzene per square yard, three nights each week until the fourth true leaf developed. After the conclusion of the treatments and following cold wet weather mildew appeared in epidemic form, indicating the necessity of continued treatments until plants are set in the field.

Predisposition of Tomato Plants to Fusarium Wilt. FOSTER, ROBERT E. Under controlled conditions, using the dip-method of inoculating tomato plants with *Fusarium oxysporum* Schl. f. sp. *lycopersici* (Sacc.) S. & H., predisposition to development of wilt was brought about by several environal factors. In plants grown prior to inoculation at soil temperatures near the optimum range for growth (20°–28° C.), wilt developed more severely than in plants grown at lower or higher soil temperatures, regardless of the soil temperature maintained after inoculation. Wilt developed more severely in plants grown prior to inoculation in dry soil than it did in those grown in saturated soil or in soil with an optimum moisture content. Those plants grown in a short day prior to inoculation had a greater degree of wilt development than did those grown in a long day. Age of tomato plants at the time of inoculation had little or no effect on the subsequent development of wilt over the range tested (10–50 days old when inoculated).

Electrophoretic Studies with the Plant Viruses. FRAMPTON, VERNON L., AND WILLIAM N. TAKAHASHI. Leaf extracts obtained from healthy tobacco plants with ordinary buffers contain three proteins, as evidenced by the scanning patterns obtained with the Longsworth apparatus, and neither the concentration nor the chemical nature of these normal proteins is altered, so far as one can determine, by infection of the plant with tobacco-mosaic virus, the potato X and Y viruses, a latent potato virus obtained from the potato variety Katahdin, with James Johnson's cucumber mosaic No. 1, or Price's indicator strain to cucumber mosaic. Two proteins are extracted from the common bean and these likewise are not influenced on infection of the plant with the common bean mosaic or Zaumeyer's bean virus No. 4. The scanning patterns of the tobacco plant and potato tubers are not influenced by age in the time interval studied. In the instances of each of the viruses indicated, an abnormality appears in the patterns obtained from the infected plants and the location of the abnormality in the pattern in each case is correlated specifically with the virus in question. The appearance of the abnormality in the pattern of tobacco mosaic virus in tobacco plants is correlated in time with the appearance of the symptoms in the plant. The scanning patterns obtained with the tobacco, tomato, and potato plants are similar and are distinct from those obtained with the bean or cucumber.

Phylogenetic Relationship of the Nine Known Leaf-hopper Vectors of Pierce's Disease of Grape. FRAZIER, NORMAN W. Three species of leaf hoppers, *Draeculacephala minerva* Ball, *Carneocephala fulgida* Nott., and *Neokolla circellata* (Baker), have previously been reported to transmit the virus causing Pierce's disease of grape. More recent work has shown that 6 additional species of leaf hoppers, *Carneocephala triguttata* Nott., *Helochara delta* Oman, *Neokolla gothica* (Sign.), *N. confluens* (Uhler), *N. heiroglyphica* (Say), and *Cuerna occidentalis* Oman and Beamer, also are able to transmit the virus. All 9 species are contained in the single subfamily Amblycephalinae, members of which are commonly known as sharpshooters. Every species of this subfamily thus far tested has proved to be a vector of the virus. Many species of leaf hoppers in other subfamilies

have been tested and not one has proved to be a vector. The present evidence strongly suggests that a phylogenetic relationship exists between the Amblycephalinae and the ability to transmit the virus.

A Pythiaceous Stem-end Rot of Potatoes. GOSS, R. W., AND J. H. JENSEN. In the 1943 potato crop a tuber rot was found with symptoms similar to those described for "leak" except that the rot usually occurred at the stem end instead of centering around wounds and usually was present when the tubers were dug. A pythiaceous fungus was isolated, which, when added in a water suspension to soil in which potato plants were growing, infected roots, stems, stolons, and tubers. Some tubers were completely rotted when dug and others had "leak" symptoms at the stem end ascribable to infection from the stolon. Infection resulting from soil inoculation was greater at 22° than at 30° C. and with high rather than low soil moisture. Isolates tested by wound inoculation of tubers produced a rapid rot at 20° to 30° C. The maximum development of the rot was at 25°, whereas only a slight amount of rotting occurred at 5° to 10° and at 35° C.

Influence of Rate, Depth, and Time of Planting Spring Wheat on the Incidence of Root Rot. GREANEY, F. J. Field experiments to determine the effect of rate, depth, and date of seeding spring wheat on the incidence of root rot caused by *Helminthosporium sativum* and *Fusarium* spp. were made at Winnipeg, Manitoba, from 1936 to 1943. In 1936, 1937, 1938, and 1939, plantings of wheat were made at 4-day intervals during May and early June (10 plantings). Each year the effect of planting time on plant emergence, yield, and incidence of root rot was constant, the severity of seedling blight and root rot increasing and percentage of plant emergence and yield decreasing with lateness of planting. In experiments from 1939 to 1943 root rot severity increased with thickness and depth of planting. Further work is necessary to elucidate the factors responsible for variations in the incidence of root rot in relation to rate, depth, and time of planting under local conditions. Soil temperature and moisture are of outstanding importance, influencing both yield and root-rot development. In the meantime, planting spring wheat not too thickly or deeply, and at the earliest feasible date, is evidently a practical method of reducing losses from common root rot in Manitoba.

The Balance of Calcium and Potassium in Relation to Club Root of Cabbage and Potato Scab. GRIES, GEORGE A., JAMES G. HORSFALL, AND H. G. M. JACOBSON. The calcium–potassium ratio as applied was varied widely at three different pH levels, acid [with $CaSO_4$], medium [with $CaCO_3$], and alkaline [with $Ca(OH)_2$]. The same experimental design was used on two fields, one sandy, the other loamy. At any given Ca–K ratio, both club root and scab followed the expected relation to pH. In both fields and for all Ca sources, scab increased as the Ca–K ratio was reduced by increasing the K and holding the Ca constant. This occurred although the pH remained constant within each Ca series. After reaching a peak, scab declined with a further decrease in the Ca–K ratio effected by holding the K at a high level while decreasing Ca. This decrease in scab occurred either at a constant pH or in a range where scab might have been expected to increase. In the low-K sandy soil, the peak was at a higher Ca–K ratio than in the relatively high-K loam soil. Except at very high Ca–K levels, the curve for club root ran a mirror image to that for scab which suggests that the effects of the Ca and K balance are inverse with the two diseases. Probably one of the effects of pH is to alter the Ca–K ratio by altering the Ca-ion concentration in the soil.

Soil Treatments and Apple Replant Survival in Xylaria mali–Infested Locations. GROVES, A. B. Black root rot of apple is widely distributed throughout the Cumberland-Shenandoah fruit-growing region and is a major factor in tree loss. The survival of replants made in locations from which diseased trees have been removed is too low to justify such replanting. Soil treatments have been resorted to in an attempt to improve the chance of replant survival during the critical early years in the life of the tree. Observations of replants growing in treated locations have now been completed for 7 seasons. A carbon bisulfide treatment appears most promising to date, with manure perhaps the poorest. Results with urea and chloropicrin treatments show promise but cannot be considered more than preliminary. Results with other treatments are less indicative.

Compatibility of Organic Fungicides and Summer Oil. GROVES, A.B. There is a most pressing need for a fungicide compatible with summer oil for use on apples where the use of an ovicide is regarded as essential to codling moth control. The standard sulphur and copper fungicides available are either not compatible with oil or are unsafe at the season required. Organic fungicides have been used on the York variety both prior to, and in combination with, summer oil. When used in combination, severe injury resulted with Compound 604, moderate injury with He-175, and light but characteristic injury with Chloranil and Puratized N5X. No injury resulted with Compound 341 or its hydrochloride form, or with Fermate. The 10-day-old residues of all organic materials proved compatible with subsequent oil applications.

Tests with New Organic Fungicides on Orchard Fruits. HAMILTON, J. M., D. H. PALMITER, AND G. L. MACK. McIntosh trees sprayed with Puratized N5X, ½ pt./100, had 2 per cent scabby fruit as against 22, 24, and 44 per cent for Isothan Q15, 1 pt./100; Fermate, 1–100; and Micronized sulphur, 5–100, respectively. Puratized N5X has the eradicative property of lime-sulphur without causing visible injury. It did not control cedar-apple rust. Q15 is also eradicative. It gave excellent control of brown rot on sweet cherries. Apparently because of poor tenacity, Q15 did not adequately control cherry leaf spot, sooty blotch and leaf blight of pear, and cedar-apple rust. Experiments on potted apple trees in the greenhouse corroborate the field data. Puratized N5X and Q15 are fungistatic, with moisture and the time element as factors in their effectiveness. Dithane alone is somewhat comparable to Fermate for control of apple scab and cedar-apple rust. Unlike Fermate, it did not control peach leaf curl or brown rot on sweet cherries. Dithane is incompatible with lead arsenate and nicotine sulphate. The arsenical mixture severely injured Cortland foliage, russeted McIntosh fruit, and defoliated Montmorency cherries. Dithane added to a zinc sulphate–lime mixture is more effective and compatible with lead arsenate. Indications were that Dithane, ¾–100, added to a zinc sulphate–lime mixture, 1–½–100, will control cherry leaf spot.

Relation of Physiologic Races of Puccinia graminis tritici to Wheat Improvement in Southern Mexico. HARRAR, J. G., W. Q. LOEGERING, AND E. C. STAKMAN. In physiologic race surveys of *Puccinia graminis tritici* made in Southern Mexico for 12 years, only races 38, 59, and 19 have been sufficiently prevalent to be of practical importance. Although these races have been generally distributed, there has been some localization in prevalence within the region. Races 56 and 17, which are very prevalent in Northern Mexico and the United States, have been found only occasionally in Southern Mexico. During the past two years many wheat varieties and hybrid lines have been tested under epidemic conditions near Mexico City. As would be expected, Marquis and certain other varieties that are completely susceptible in the spring-wheat region of the United States were highly resistant to stem rust. Rival, Newthatch, Regent, Renown, Pilot, Mida, and certain other varieties recently produced in the United States and Canada were almost free from stem rust and highly resistant to leaf rust, but all matured two or three weeks later than certain early but very susceptible commercial varieties commonly grown in Mexico. Appropriate crosses, therefore, are being made to combine earliness with rust resistance. (Cooperative investigations between the Secretaría de Agricultura y Fomento de México, the Rockefeller Foundation, the U. S. Department of Agriculture, and the Minnesota Agricultural Experiment Station.)

Varietal Variation and Inheritance Studies on Natural Water-soaking in Tobacco. HEGGESTAD, HOWARD E. Natural water-soaking in several foreign, domestic, and local varieties of tobacco was compared under moist-chamber and outdoor-seedbed conditions. The percentage of plants water-soaked varied from 100 to 8; and a score, based on leaf area water-soaked, varied from 2.36 to 0.09. Crosses between several susceptible and resistant varieties indicate that resistance may be partially dominant in the F_1. The F_2 and F_3 generations clearly indicate segregation of genetic factors. Some F_3 lines approach the resistance and the susceptibility of the parents. The inheritance of natural water-soaking appears to be governed by multiple factors. Water-soaked plants in several series of tests were atomized lightly with the wildfire organism. One moist-chamber test yielded an average of 18.5 lesions per plant on one variety as compared to 3.9 lesions on another. Following water-soaking, scores of 2.47 and 0.67, respectively, were obtained on these same varieties. Varietal infection in tobacco seedbeds varied from 34 to 1.2 lesions per leaf, relative susceptibility to the disease being correlated with relative susceptibility to water-soaking. Varietal variation in water-soaking was found in tomatoes, oats, and corn. Inoculation with the halo-blight organism on oats exposed to natural water-soaking yielded results similar to those on tobacco.

Growth of Tobacco Seedlings Stimulated by the Addition of Peanut-hull Meal to the Plant-bed Soil. HENDERSON, R. G. Treatment of tobacco plant-bed soil with urea and calcium cyanamid for the control of weeds leaves the soil toxic to plant growth for several weeks. In preliminary tests the addition of organic matter to treated soil, in order to stimulate the growth of microorganisms, quickly brought the soil back to productive state. In an extensive test at Chatham, Virginia, in 1943–44, treated soil amended with 2 lb. of peanut-hull meal per square yard produced more vigorous plant growth and a larger number of usable tobacco plants than did treated soil left unamended. Analyses of soil samples taken 41 days after the peanut-hull meal was added revealed no significant differences in pH or ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen content between the amended and unamended plots. No analyses were made after the 41st day. The growth stimulation from the use of peanut-hull meal probably was due in part to improvement of the physical condition of the soil, since some stimulation was noted also on plots where neither urea nor calcium cyanamid was used. From these data it appears

that the benefits obtained from treating soil with urea and calcium cyanamid can be increased by adding organic matter.

Zinc Dimethyl Dithiocarbamate and the Control of Early Blight and Anthracnose on Tomatoes and of Leaf Hoppers and Early Blight on Potatoes. HEUBERGER, J. W., AND D. O. WOLFENBARGER. In experiments on tomatoes and potatoes, designed to determine the protective value of organic and inorganic fungicides, zinc dimethyl dithiocarbamate was an outstanding material. In all tests the fungicides were used at a concentration of 1.5–100 active ingredient. The percentages of control of early blight of tomato on Sept. 28 were 75 for Bordeaux, 71 for zinc dimethyl dithiocarbamate, 66 for Compound A, 52 for Fermate, and 24 for the untreated; the percentages of tomato anthracnose infection at the September 28 harvest were 0.5 for zinc dimethyl dithiocarbamate, 9.3 for Bordeaux, 10.4 for Compound A, 18.0 for Fermate, and 25.3 for the untreated. The percentages of control of early blight on Sept. 27 on late-planted Dakota Red potatoes was 97 for Bordeaux, 92 for zinc dimethyl dithiocarbamate, 90 for Compound A, 80 for Fermate, and 65 for the untreated. The Ca, Na, Fe, Cu, and Pb dimethyl dithiocarbamates were less effective fungicides than was Zn dimethyl dithiocarbamate. On early-planted Irish Cobbler potatoes the percentages of control of potato leaf hoppers (*Empoasca fabae* Harr.) were 50 for zinc dimethyl dithiocarbamate, 38 for zinc sulphate–lime (1–½–100), 34 for Bordeaux, 28 for Compound A, and 16 for the untreated. Adding zinc sulphate–lime (1–½–100) to organic and inorganic fungicides increased leaf-hopper control by approximately 20 percentage points for each material. Yield records were not complete when this abstract was submitted.

Preliminary Report on DDT in the Potato Fungicide Program. HEUBERGER, J. W., AND D. O. WOLFENBARGER. In an experiment comprising 44 materials on late-planted Dakota Red potatoes, DDT (dichloro diphenyl trichlorethane) at a concentration of ¾–100 was used alone and in combination with the two fungicides, Compound A (copper oxychloride) and zinc dimethyl dithiocarbamate, in a 5-application spray schedule. Single row plots 20 feet long were used in a replicated, randomized block design. Potato leaf hopper (*Empoasca fabae* Harr.) counts on September 8 averaged approximately 7.6 per 20-foot row for those treated with fungicides and those untreated, and averaged 1 for DDT alone or combined with Compound A and zinc dimethyl dithiocarbamate. DDT had no effect on control of early blight (*Alternaria solani*) when used either alone or in combination with the fungicides. Where DDT was used alone or combined with the fungicides, the plants were taller, broader, darker green in color, and had larger leaflets; also, the leaflets were flatter (less cupped) than when untreated or when the fungicides were used alone. No foliage injury was observed where DDT was used. The border effect of DDT was pronounced, as replicates of other treatments that fell next to the DDT had characteristics of the DDT plots. No yield records were available when this abstract was submitted.

The Cherry Virus Complex in New York. HILDEBRAND, E. M. Several nonlethal abnormalities of virus or genetic origin occur on cherries in New York. The graft-transmissible nature of certain elements in this complex was first demonstrated in 1936. Subsequently four virus diseases have been distinguished in the complex on sour cherry—yellows (*Chlorogenus cerasae*), ring spot (*Annulus cerasae*), green-ring yellows, and rosette—and two on sweet cherry—tatter-leaf and mottle. The seed-transmissible crinkle on *Prunus avium* appears to be of genetic origin. The several cherry viruses are transmitted readily by grafting and produce distinctive symptoms. On Montmorency the incubation periods of ring spot and rosette are short (± 2 weeks) and that of yellows and green-ring yellows is long (± 1 year) whereas on Black Tartarian that of tatter-leaf virus is short (± 2 weeks) and that of mottle is long (± 1 year). When indexed on peach, ring spot ordinarily is distinguished by necrosis followed by recovery, whereas yellows induces (1) rosette and stunting, (2) mosaic, or (3) no symptoms. When indexed on Italian prune, yellows (strain 1) and sweet-cherry mottle induce symptoms simulating prune dwarf. The fact that certain of these viruses have been located in the rootstocks and grafted trees in nurseries and also in the wild (*P. avium, P. virginiana, P. pennsylvanica*) suggests their probable origin.

Effect of Crown-gall Bacterial Metabolites, Crown-gall Tissue Extracts, and the Composition of the Medium on Growth in vitro of Excised Tobacco and Sunflower Tissue. HILDEBRANDT, ALBERT C., A. J. RIKER, AND B. M. DUGGAR. In connection with crown-gall studies, the effects of various modifications of the culture medium on the growth *in vitro* of excised tobacco and sunflower tissue were observed. White's synthetic medium was used with various supplements. When fermented media from both the virulent and attenuated cultures, respectively, of *Phytomonas tumefaciens* (Smith and Town.) Bergey *et al.* were added, slight stimulation of tobacco tissue occurred at the lower concentrations of the fermented material. A slight inhibition was found at the higher concentrations. Fermented media from the attenuated strain strikingly inhibited sunflower

tissue at all except the lowest concentrations. Extracts from crown galls on marigold stimulated growth of both tissues at all concentrations; Paris daisy gall extract similarly favored the sunflower tissue, and yeast extract the tobacco tissue. Tomato gall extract and yeast extract, respectively, stimulated sunflower tissue at low concentrations but inhibited growth at higher concentrations; tomato gall extract similarly affected tobacco tissue. Paris daisy gall extract inhibited growth of tobacco tissue at all except the lowest concentrations. Varying concentrations of important mineral salts and vitamins were studied in 120 different combinations involving 22,000 tissue transplants. These have indicated what happened when the basic medium was altered. Improved media were developed.

Some Ontogenic Characteristics of Ustilago linearis forma hordei. HIRSCHHORN, ELISA. Since collections of *Ustilago linearis* studied by Osner, Davis, and Fischer differed physiologically, morphologically, and pathogenically, certain ontogenic characters of forma *hordei* of *U. linearis* were studied in plants of *Agropyron trachycaulum* (Link) Malte growing in the greenhouse. Soon after infection, hyphae reach the base of the coleoptile. Within 10 days the mycelium can be found between and within parenchyma cells and in the vascular tissues, being especially conspicuous near the xylem vessels and near nuclei of the host cells. Actively growing hyphae have long, binucleate cells. Within 6 weeks vegetative host tissues are fully invaded, and chlamydospores begin to form in terminal cells of hyphae growing in the parenchyma between the vascular bundles. Caryogamy occurs just before or at the time echinulation begins. Echinulations of the young epispore shrink as the chlamydospore matures. Mature chlamydospores are uninucleate and have a single membrane, the epispore.

Fungicidal Action of Reagents for Amino Acids, Amines, Aldehydes, and Other Reactive Cell Constituents. HORSFALL, JAMES G., AND GEORGE A. ZENTMYER. Zentmyer's theory (Phytopath. 33: 1121, 1943) that 8-hydroxyquinoline is fungistatic because it precipitates essential metals in the spore suggested that other reagents for metals or reagents for other products of intermediary cell metabolism might also be fungistatic, possibly fungicidal. The following reagents for essential metals were previously known or are here shown to be fungistatic: "cupferron," K-periodate, resorcinol, Na-diethyl dithiocarbamate, thiourea, thioglycolic acid, hydrogen sulphide, alizarine, benzidine, α-benzoin oxime, *o*-benzoquinone dioxime, catechol, cinchonine, aniline, dithio-oxamide, malonic acid, nitrobenzene-azo-α-naphthol, phenylhydrazine, K-ethylxanthate, quinalizarin, salicylaldoxime. Similarly, reagents for amines or for amino acids that are fungistatic are: ammonium rhodanilate, *p*-bromo benzenesulphonyl chloride, 3-5 dinitrobenzoyl chloride, *m*-nitrobenzene sulphonyl chloride, *p*-nitrophenyl isocyanate, Na-3-naphthoquinone-4-sulphonate, *p*-toluenesulphonyl chloride, Reinecke salt. Fungistatic reagents for aldehydes are: α-benzyl-α-phenylhydrazine hydrochloride, dimethyldihydroresorcinol, 3-5 dinitrosalicylic acid, α-naphthol, α-naphthylhydrazine hydrochloride, phenylhydrazine, benzenesulphohydroxamic acid. A few reagents for these groups were nonfungistatic.

Derivatives of Pyridine and Quinoline as Cationic Fungicides. HOWARD, F. L., H. L. KEIL, AND H. H. MOSHER. Monobasic acid derivatives of pyridine, picolines, lutadines, collodine, quinaldines, quinoline, and isoquinoline have been developed that exhibit high fungitoxicity, low phytotoxicity, and surface activity as desired. Examples of soluble cationic forms are cetyl isoquinolinium bromide, lauryl pyridinium thiocyanate, lauryl quinaldinium bromide, and lauryl isoquinolinium acetate, which follow the general pyridine ring structure (see following abstract). These compounds are fungitoxic and stable over a wide pH range (pH 3 to pH 9), commercially available from inexpensive noncritical materials, and reportedly not poisonous to higher animals. Assays of fungitoxicity to spores of *Macrosporium sarcinaeforme* have given mean LD50 values of 0.5 ppm. to 20 ppm. and mean LD95 values of 1.5 ppm. to 50 ppm. when the data are plotted on logarithmic-probability paper. Phytotoxicity determinations on tomato, bean, apple, and potato foliage indicate a considerable margin of safety. Toxicant concentrations of 1:5000 seem adequate as foliage sprays and as antiseptic fruit washes. The compounds are compatible with insecticides and adjuvants, except soaps. The wetting property, solubility, and resistance to weathering can be varied to meet specifications by altering the molecular structure.

Nicotinium Derivatives as Fungicides. HOWARD, F. L., H. L. KEIL, L. WEIL, AND C. F. WOODWARD. Twenty-five non-metallic derivatives of nicotine, in which an alkyl, aralkyl, or substituted aralkyl radical (R) and an acid radical (X) were attached probably to the nitrogen in the N-methyl pyrrolidine ring, have been prepared and tested for fungitoxicity, phytotoxicity, and surface activity. Laboratory assays of toxicity to *Macrosporium sarcinaeforme* spores have shown general relationships between the molecular structure of the radicals added and the fungitoxicity. Lethal dose (LD50) values can be varied from 11 ppm. to 2000 ppm. and LD95 values from 23 ppm. to greater than 3000 ppm. by attaching different, R and X, radicals to the N-methyl pyrrolidine nitrogen atom.

There is no correlation between fungicidal value and nicotine content or molecular weight. Derivatives having benzyl and short-chain alkyl (R) radicals exhibit much lower fungitoxicity than those having lauryl or cetyl (R) radicals. The margin of safety between fungicidal action and injury to foliage can be estimated by comparing LD50 values for fungitoxicity with LD50 phytotoxicity values; *i.e.*, the mean dose by which 50 per cent of tomato foliage is killed within 5 days after having been immersed for 5 seconds. The mean LD50 fungitoxicity value of benzyl nicotinium chloride was 210 ppm. and of lauryl nicotinium oleate 11 ppm., while the mean LD50 phytotoxicity values were 20,000 ppm., and 4000 ppm. respectively.

Water Influencing Host-predisposition. JOHNSON, JAMES. Efforts were made to separate and measure the "forms" of water affecting host-predisposition to disease. High atmospheric humidity, plant-surface water, and water-content of the plant cells themselves are not determining factors in host predisposition to many diseases except as these conditions influence a fourth form of water favoring invasion. Little information exists relative to excessive water in the intercellular spaces and vascular tissues, the extreme of which is known as "water-soaking." The more inclusive and descriptive term "water-congestion" is suggested. Water-congested tissues may be visible only by magnification, or the spaces may be only partly filled with water and not demonstrable. Determinations of the total water content of tissues on a variety of species were made throughout the growing season during varying weather conditions. By this method, increases attributable to water-congestion were not significant. The total water-content of 50 species varied from 59 to 96 per cent, but each remained fairly constant through varying periods of weather and predisposition to disease. Artificially induced water-congestion in varying degrees yielded better percentage comparisons than did plants under normal conditions. An increase of 2 per cent in the total water-content resulted in macroscopically visible signs of water-congestion. Through wilting and subsequent complete water-congestion, the green weight of some leaves may be doubled.

Bacterial Invasion through Stomata. JOHNSON, JAMES. Experiments on the nature of disease resistance require additional evidence of infection without the intervention of microscopic-sized wounds or the propulsion of organisms through stomata by external force. Water-congested leaf tissue results in extreme predisposition to tobacco blackfire and wildfire. Water-soaking by atomizing may result in wounding, and the atomized inoculum may propel organisms through the stomata. Water-congestion produced by the internal water-pressure method, followed by inoculum applied in droplets, eliminates both probabilities. On such water-congested leaves, India ink and bacterial suspensions enter instantaneously, gradually, or not at all, depending upon certain circumstances including stomatal opening. Slight wounding of the water-congested areas results in instant entrance due to capillary tension, and the same force operates through stomata but normally at a slower rate. The size of disease lesions depends chiefly upon the time water-congestion remains in the inoculated area. Bacterial invasion through stomata is less certain than that through wounds, but is sufficiently certain to account for heavy infections frequently found following weather conditions favorable for water-congestion. Under such conditions, for example, dew is sufficient to suspend the parasite and make surface water contact with the water-congestion areas through stomata, permitting invasion to occur by capillary action.

A Spray Boom Adapted for Ground-spraying to Combat Apple Scab. KEITT, G. W. For two seasons spray booms have been designed and tested for increasing speed, economy in cost and manpower, and effectiveness of applying the Elgetol ground treatment. The booms used gave good results. The current model, attached to the rear of the spray rig, is 17 feet long and carries 16 nozzles approximately 18 inches from the ground. It is provided with a shield against low branches, a joint that permits disengagement upon contact with a tree, and a device to avoid excessive variation in distance of the nozzles from the ground. Two men using a rig with a 25-gallon-per-minute pump and 300-gallon tank applied the ground treatment to approximately one acre an hour. In a season of severe scab on McIntosh in unsprayed or inadequately sprayed orchards in 1944, scab development on McIntosh in the experimental ground-sprayed orchard was retarded, mild, and easily controlled. Unsprayed McIntosh trees had 72 per cent of their fruit scabbed at harvest. Various mild programs gave less than 1 per cent of fruit scabbed; *e.g.*, 8 applications of Flotation Sulphur or 3 applications of lime-sulphur before bloom and 5 applications of Flotation or Mike Sulphur or Fermate after bloom. Some blueprints of the boom are available.

Fruit Invasion and Seed Carriage of Tomato Fusarium Wilt. KENDRICK, JAMES B. Vascular invasion by the tomato Fusarium wilt organism (*Fusarium oxysporum* f. *lycopersici*) often extends into the fruit pedicel. Seed removed aseptically from the interior of 265 ripe fruits showing pedicel invasion and planted on potato-dextrose-agar plates showed 20.7 per cent of the fruits to be harboring the wilt organism on the seed. Sixty-

day-old seed extracted from fruits showing a high percentage of *Fusarium* on the seed was treated with a 1–1000 mercuric chloride solution for 5 minutes, washed in sterile water, dried, and planted as whole and as cut seed on agar plates. The whole treated seed remained sterile while the cut seed showed 9.6 per cent and the nontreated seed 100 per cent *Fusarium* growth. Nontreated seed from the same lot planted in sterilized greenhouse soil produced 53.7 per cent wilt-infected plants. Preliminary laboratory trials showed that hot water at 54° C. for 30 minutes did not completely eliminate *Fusarium* from the seed while seed treated with mercuric chloride, 1–2000 for 5 minutes, or New Improved Ceresan, 1–1200 for 5 minutes, showed no *Fusarium* growth on agar plates.

Rhizopus Stem Blight of Tomato. KENDRICK, JAMES B. The canning tomato crop in Central California annually suffers considerable damage from a Rhizopus fruit rot and subsequent blighting of the stem. The fungus enters the early-ripened fruit through growth cracks, worm damage, or other injuries, usually on fruits under heavy foliage where the atmospheric moisture is rather high. After the fruit is entered by the fungus, it becomes a soft watery mass, then loses its watery contents and becomes mummified on the pedicel. In many cases, the fungus penetrates the fruit pedicel, fruit spur, and main branch, causing a blighting of the entire fruit spur and producing elongated dark brown, sunken lesions on the main branch above and below the point of attachment of the fruit spur. Once the fungus enters a main branch of the plant, the leaves show a yellowing and blighting often mistaken for Fusarium wilt. Cultures from internal discolored pedicel and stem tissue have consistently yielded a species of *Rhizopus* similar to *R. nigricans*.

Some Factors That Influence After-ripening of Smut Chlamydospores. KREITLOW, K. W. Chlamydospores of *Ustilago striaeformis* from *Poa pratensis* were after-ripened in host tissue free of contaminating organisms. Spores prepared free of host tissue were after-ripened successfully on filter-paper strips incubated at 35° C. in a moist chamber. Agitating chlamydospores in a Waring Blendor hastened after-ripening and enhanced germinability. Fresh chlamydospores stored at 5° C. for 60 days and then transferred to an incubator at 35° C. required longer to after-ripen than similar spores stored at 25° C. Water in contact with spores was necessary for successful after-ripening. Spores in a saturated atmosphere required longer incubation than when in contact with water, while spores incubated dry failed to become germinable.

Transmission of Virus from X-Diseased Peach Trees to Herbaceous Plants. KUNKEL, L. O. A virus was transmitted from X-diseased peach trees to carrot, parsley, periwinkle, and tomato by means of dodder, *Cuscuta campestris* Yuncker. It was readily transmitted from diseased to healthy plants of each of these species, but all attempts to take it from peach to peach or from these species to peach failed. Since the virus was transmitted from X-diseased trees of four different orchards but could not be obtained from healthy-appearing trees of the same orchards, it seems probable that it was the X-disease virus. In tomato it caused wilting and death; in carrot and parsley it caused chlorosis of young leaves but reddening and yellowing of old leaves; in periwinkle it produced yellowing in both old and young leaves and marked stunting of flowers. All plants into which it was introduced, except tomato, assumed an upright habit of growth and produced an abnormal number of secondary shoots.

The Identity of the Virus Causing Punctate Necrosis and Mottle in Potatoes. LARSON, R. H. Evidence that the virus causing a necrosis and mottle in potatoes is an aberrant strain of the potato latent ring-spot virus has been secured. The virus is transmitted easily by plant extract but all attempts at transmission by means of aphids have failed. The virus remains infective *in vitro* for 28 to 30 days at 20° to 22° C., tolerates a dilution of 1 to 10,000, is inactivated when held at about 66° to 67° C. for 10 minutes, and by drying. Severe symptoms are produced in potatoes at 14° to 16° C. and very mild symptoms when infected plants are held at 24° C. or higher. All Solanaceae tested are readily infected. *Atropa belladonna* L. is a symptomless carrier. Necrotic lesions are produced on the inoculated leaves of *Amaranthus retroflexus* L. and *Digitalis lanata* L.; the virus is not systemic in these hosts. Potato seedling 41956 is immune. Strains of the potato latent mottle virus effectively immunize against the ring-spot virus as measured on such differential hosts as *Nicotiana tabacum* L., *N. glutinosa* and *N. rustica* L. Mixed infections of the ring-spot virus with the veinbanding virus and tobacco mosaic confirmed its affinity with the potato latent ring-spot virus. No evidence was obtained suggesting that more than one virus was concerned.

Further Studies on the Nature and Cause of Purple-top Wilt of Potatoes. LEACH, J. G., AND C. FRANKLIN BISHOP. A 5-year study of purple-top wilt (blue stem) of potatoes in West Virginia has led to the following conclusions: The disease is caused by the aster-yellows virus and is transmitted to potatoes chiefly by viruliferous aster leaf hoppers that have survived the winter as adults. The incubation period of the virus is

longer in potatoes than in asters. Infection must take place not later than early July (in West Virginia) to produce symptoms on late potatoes maturing in early September. Early varieties in West Virginia usually mature before completion of the incubation period, whereas they are severely affected farther north. This probably can be explained by differences in mass movements of leaf hoppers in different regions. All attempts to transfer the virus from potatoes to asters or potatoes, either by grafting or by leaf hoppers, have failed. No satisfactory explanation for these failures can be given. The virus is not perpetuated through tubers from infected plants, although plants from such tubers have low vigor. No practical control measures can be recommended. Low tolerance in certified seed would not aid in control but would tend to insure greater vigor. Roguing to meet a tolerance limit established for this purpose would be justified if tubers were removed.

Inoculation Methods for Testing Blue Grass for Stripe-smut Resistance. LEACH, J. G., AND CONLEY V. LOWTHER. Numerous methods of inoculating blue grass with stripe smut (*Ustilago striaeformis*) have been tested. The conventional methods of seed inoculation, with or without vacuum treatment and with the use of various types of inoculum, have resulted in such low percentages of infection, and the incubation periods have been so long, that they are considered impractical for eliminating susceptible strains. Inoculation of plants near their growing points by means of a hypodermic syringe and with fresh spore suspensions, has given better results. With this method, the incubation period has been as short as 13 days, compared with 6 weeks for seed inoculation. An important advantage of the hypodermic-syringe method is that, without resorting to seed production, clonal selections can be reinoculated over and over, with adequate replications, until resistance or susceptibility is determined definitely.

Growth Rates of Host and Pathogen as Factors Determining the Severity of Pre-emergence Damping-off. LEACH, L. D. Neither the growth rate of the pathogen nor the emergence rate of seedlings adequately explains the relation of temperature to the severity of pre-emergence damping-off. The ratio of the coefficient of velocity of seedling emergence to the growth rate of the pathogen, however, is inversely related to the severity of infection in all combinations of host and pathogen tested. For example, spinach which at low temperature has a relatively greater growth rate than *Pythium ultimum* suffers less pre-emergence damping-off at 4° and 8° C. than at higher temperatures where the ratio of growth rates is reversed. Conversely, watermelons and other high temperature crops show decreasing pre-emergence infection from the same pathogen with each elevation in temperature, a relationship that corresponds to the ratio of growth rates of watermelon and *Pythium ultimum* at these temperatures. A study of ten combinations of hosts and pathogens indicate that this principle has fairly general application. Evidence has also been obtained that seed lots of the same variety differ in susceptibility to Pythium damping-off, a condition apparently correlated with differences in vitality as indicated by emergence rates.

Effectiveness of Seed Treatments Against Surface-borne Ascochyta on Pea Seeds. LEACH, L. D., AND W. C. SNYDER. It has been reported that seed-borne *Ascochyta* is only partially controlled by chemical seed treatments. Failure to obtain complete control may be presumed to be due to internal infection of the seed. Most lots of pea seeds are believed to be relatively free from internally borne infection but in some years many lots carry surface-borne *Ascochyta*. Disease-free pea seed was inoculated by being dipped in a suspension of *A. pinodella*, dried, then treated with various fungicides and planted in sterilized soil. None of the dust treatments completely prevented infection from the surface-borne fungus, but even with the heavy inoculation used, some of the dust treatments gave a high degree of control. At the highest dosages the materials, in descending order of effectiveness, were dichloronaphthoquinone (no. 604), Arasan, Semesan, New Improved Ceresan, Ceresan, Spergon, yellow copper oxide. The dosages of several dusts had a striking effect upon results. Complete elimination of surface-borne *Ascochyta* resulted when seed was dipped in a solution of ethyl mercury phosphate.

Dusting Soybeans for Control of Bacterial Pustule. LEHMAN, S. G. Little information is available on the effect of spraying or dusting soybean plants to control disease. In 1944, a field experiment was set up to determine how much reduction of bacterial pustule (*Xanthomonas phaseoli sojense*) may be expected from dusting the plants with fungicides. The dust preparations used were: (a) 325-mesh sulphur, (b) copper-talc containing 6 per cent metallic copper, and (c) copper-sulphur containing 6 per cent metallic copper. Half the dusted and control plots were inoculated by spraying with *X. phaseoli sojense*. Sulphur dust failed to reduce bacterial pustule. The copper-talc and copper-sulphur dusts were more effective. The variety Tokio had 62 and 90 per cent infected leaves, respectively, in the uninoculated and inoculated control plots and 33 and 51 per cent on correspondent plots dusted with copper-talc. More obvious disease reduction was observed in the number of infections per leaf. Uninoculated and inoculated

undusted plants showed respectively 12 and 60 infections per leaf, but only 3 and 12 infections per leaf were found on correspondent plants dusted with copper-talc. On the more susceptible Herman variety 30 and 100 infections per leaf were found, respectively, on uninoculated and inoculated undusted plants, and only 6 and 15 infections per leaf occurred on correspondent dusted plants. The copper-sulphur dust gave disease reductions closely paralleling those of copper-talc.

An Isoquinolinium Fungicide for Apple Scab Control. LOCKE, S. B. Isothan Q15 (lauryl isoquinolinium bromide), a water-soluble, surface-active, cationic fungicide, was compared with six other materials for apple scab control in an orchard test involving six spray applications on ten single-tree replicates. This toxicant at 1: 5,000 reduced the amount of scab on McIntosh foliage 94.0 per cent below that on unsprayed check trees. Wettable (Camden Paste) sulphur at 1: 80 gave 93.4 per cent control, while Puratized N5D at 1: 20,000 gave 99.6 per cent control. Isothan Q15 and Puratized N5D have therapeutic value as shown by data obtained from tagged leaves. The number of sporulating lesions on McIntosh foliage was reduced 77.2 per cent by one application of Isothan Q15 at 1: 5,000, and 76.9 per cent by one application of Puratized N5D at 1: 20,000. This therapeutic effect is believed to account, in part, for the control obtained. The solubility of Isothan Q15 permits a low minimum effective dosage. Its surface activity increases dispersion of added lead arsenate, reduces arsenical injury, gives a more uniform deposit, and produces better coloring of the fruit.

Deposition of Fungicides and Insecticides on Cherry Foliage. MACK, G. L., J. M. HAMILTON, AND A. W. AVENS. Ineffectiveness of dusts for controlling cherry leaf spot is attributed to inadequate deposition on the under side of the leaves because of lack of moisture. An attachment to a standard duster which allows liquid to be atomized into the dust stream overcomes this difficulty. The deposition of copper materials, sulphur, and lead arsenate applied in equivalent amounts as sprays, dusts, and spray-dusts was compared by chemical analysis of the residues. The copper and arsenic content of the residues from dry dusting was less than half that obtained by spraying. Impregnating dust with oil, 3 per cent by weight, did not increase deposition appreciably. An aqueous 0.1 per cent solution of polyvinyl alcohol applied as a spray-dust doubled the deposit of both copper and arsenic and used only about one-tenth as much liquid as was required for spraying. Leaf-spot control varied directly with the copper content of the residues. Control of leaf spot equal to that secured by spraying was obtained also by the use of a concentrated oil emulsion.

Hop Twine Treatment in Controlling Downy Mildew. MAGIE, R. O. Chemical treatment of twine used to support hop vines partially protected the terminal and lateral buds during May from infection by hop downy mildew (*Pseudoperonospora humuli*). Suspensions and solutions of fungicides in which cotton and binder twines were soaked for 1943–44 field and laboratory tests were Bordeaux, 60–20–100; Tribasic copper sulphate, 6 per cent; Yellow Cuprocide, 4 per cent; Fermate, 4 per cent; U.S.R. No. 604, 2 per cent; No. 604, 1 per cent in chloroform; Spergon, 10 per cent in benzene; saturated water solution of Dithane; Pentachlorphenol, 10 per cent in alcohol; Puratized LN (phenyl mercuri 9, acetoxy 12, octadeconoic acid), 1 per cent, plus Vatsol, 0.2 per cent. Triton X100, 0.25 per cent, was added to water suspensions in 1944 to wet the twine. Puratized LN and U.S.R. No. 604, the more effective materials, permitted one-tenth to one-fifth as much bud infection as was present where the twine was not treated. The copper materials, pentachlorphenol, and Dithane were intermediate; Fermate and Spergon were less effective. The materials fell into the same order of effectiveness when leachings from the weathered twine were tested against sporangia of *P. humuli* on glass. Volatile solvents facilitated the penetration of twine by organic fungicides. Hop vines trained on poles instead of twine were protected similarly by spraying the stacked poles in late winter with the copper materials at 2 per cent copper concentration.

Evaluating Fungicides by Means of Greenhouse Snapdragon Rust. MCCALLAN, S. E. A. A greenhouse method has been developed for evaluating foliage fungicides against a representative rust disease. Plants are sprayed and inoculated under controlled conditions with apparatus developed for tomato diseases (Contrib. Boyce Thompson Inst. 13: 93. 1942). Potted snapdragon plants, variety Cheviot Maid Supreme, are trained to 2 stems and tested when 12 inches tall. Total pustules per 20 leaves, following inoculation with 100,000 spores per cc., are counted 10 days later. Infection occurs readily from 5° to 20° C., with the optimum at 10° to 15° C. The number of pustules is converted to percentage of checks. Straight lines were obtained on logarithmic probability paper, from a dosage series with nine representative commercial fungicides. Empirical probit weights gave highest precision at the LD95 level, as for tomato diseases. One plant per dose suffices, but tests should be repeated. Organic compounds gave the steepest curves and most efficient control, sulphur compounds were intermediate, while copper fungicides with flat slopes were ineffective. Absolute comparisons with laboratory slide-germination

tests showed good agreement with sulphur and organic compounds, but copper fungicides were overrated in the laboratory. Final results are expressed as per cent dosage for 95 per cent control (LD95), or per cent disease at 0.2 per cent spray.

The Use of Venturia inaequalis and Sclerotinia fructicola with Pure Chemical Stimulants in Slide-germination Tests of Fungicides. MILLER, HAROLD J. The recommended procedure of the American Phytopathological Society involves centrifuging of the spore suspension, after which it is necessary to add a stimulant (1) to insure germination above 90 per cent on check slides and (2) to adjust the LD50 to a given concentration of a standard fungicide. Orange juice fulfills both requirements for *Venturia inaequalis* and *Sclerotinia fructicola*. However, different samples of orange juice have caused as much as a fourfold difference in the LD50 value of a dried Bordeaux-mixture deposit. Potassium and sodium citrates at concentrations of 0.001 per cent when used with 0.2 per cent sucrose gave an LD50 in the same range as 0.1 per cent orange juice with less than a two-fold variation and equally good germination on the check slides. There is a linear relationship between concentrations of orange juice, sodium citrate, and potassium citrate and the LD50. Malic and citric acids also have the same properties.

High Calcium vs. High Magnesium Lime in the Preparation of Bordeaux Mixture for Cherry Leaf-spot Control in Wisconsin. MOORE, J. DUAIN. Over a 4-year period, analyses of spray residues on cherry leaves after periods of weathering showed greater retention of copper when Bordeaux was made with high magnesium than with high calcium lime. These differences were obtained with both the 3-spray, 6–8–100 program and the 4-spray, 3–4–100 program, but were somewhat more striking with the 3-spray schedule. The greater difference in the 3-spray program appears to be a consequence of the longer period of weathering in this program wtihout renewal of coverage between the second application and the post-harvest one. Control of cherry leaf spot generally was about the same, whether high calcium or high magnesium lime was used. However, in the years of protracted dry periods with heavy dews, greater defoliation due to spray injury occurred on plots on which Bordeaux made with the high calcium lime was used. When differences in fruit size were obtained between plots sprayed with Bordeaux mixtures made with the two limes, these differences favored the use of high magnesium lime.

Host Range Studies of Necrotic Ring Spot and Yellows of Sour Cherry. MOORE, J. DUAIN, AND G. W. KEITT. Buds from Montmorency trees carrying (1) only necrotic ring spot or (2) cherry yellows and necrotic ring spot were inserted in nursery trees of several varieties of peach and various other species and varieties of *Prunus*. In all cases in which symptoms were expressed, except on *P. cerasus*, the same symptoms were obtained on a given host with either bud source, suggesting the necrotic ring-spot virus as the cause. Budding into ring-spot-free and yellows-free Montmorency from the plants that had been budded a year before from sources (1) and (2) gave only necrotic ring spot if source (1) had been used originally. Both necrotic ring spot and yellows symptoms were obtained on Montmorency trees budded in the spring of 1943 if source (2) had been used originally. Yellows readings on trees budded in the spring of 1944 are not completed. Neither the Abundance nor the Burbank plums used expressed any symptom when budded with either bud source, and neither gave evidence of being a symptomless carrier for either ring spot or yellows. Thus far, all attempts to obtain yellows free from ring spot have failed.

A New Organic Fungicide, 2, 3-dichloro-1, 4-naphthoquinone: Its Value as a Control for Certain Defoliation Diseases of the Tomato. NAGEL, C. M. Results during the 1944 season indicate that 2, 3-dichloro-1, 4-naphthoquinone offers promise in the control of foliage diseases of tomato. Three pathogens which caused epiphytotics during the current season are, in order of importance, *Phytomonas vesicatoria*, *P. punctulans*, and *Septoria lycopersici*. The materials used were: Yellow Cuprocide; DDT, [2, 2-bis (parachlorophenyl) 1, 1, 1-trichloroethane]; Fermate; Copper Hydro 40; 2, 3-dichloro-1, 4-naphthoquinone; He 175; Spergon; and Bordeaux mixture. All materials except Copper Hydro 40 were used as sprays while the first three were used both as sprays and as dusts. Four applications were made between July 14 and August 17. The 2, 3-dichloro-1, 4-naphthoquinone markedly excelled all other materials tested in maintaining plant foliage and caused little or no foliage injury. It was applied at the rate of 1.5 pounds per 100 gallons of water. Yellow Cuprocide ranked second. At the recommended dosages other materials offered little or no protection to foliage. The tomato variety Victor was used in the experiment in a randomized block design with four replications.

The Influence of Temperature on the Susceptibility of Potatoes to Bacterial Soft Rot. NIELSEN, L. W., AND F. A. TODD. Potato tubers exposed to sublethal temperatures become more susceptible to bacterial soft rot. Irish Cobbler tubers were used in laboratory studies on the mechanism associated with this increased susceptibility. Potatoes were stored 10 to 20 days at temperatures from 4° to 40° C. Samples of stored tubers also were heated at 47° C. for 60 minutes as a sublethal treatment. Analyses of juices

from stored and heated tubers showed that increased susceptibility was not correlated with any sugar changes induced by temperature treatments. Changes in cell-membrane permeability were determined from analyses of the sugar contents of diffusates obtained by suspending diced potatoes in distilled water for 2 hours at room temperature. The sugar contents of the diffusates were closely related to the temperature treatments. Exosmosis of sugars progressively increased from potato tissue stored at temperatures above 30° C. The sublethal treatment increased exosmosis from potatoes previously stored below 35° C. The exosmosis of sugars from potatoes stored above 26° C. was correlated closely with bacterial soft rot of early potatoes held four days at the same temperatures. At sublethal temperatures, cell membrane permeability to sugars is a reversible reaction. Possibly it is a factor associated with bacterial soft rot of potatoes exposed to high temperatures during harvest.

Anthracnose of Garden Pea. OU, S. H. Anthracnose (*Colletotrichum pisi* Pat.) occurs commonly on leaves, stems, and pods of the host in Wisconsin pea fields, but is found practically always in association with *Mycosphaerella pinodes* (Berk. and Blox.) Stone. Artificial inoculation results in weak infection of leaves but in no signs of disease on the stems. In nature its conspicuous development appears to be as a secondary parasite following *Mycosphaerella*. All original isolates from naturally infected plants sporulate sparsely on solid media and atypical cylindrical conidia form freely in various liquid media. Colonies on solid media commonly produce sectors in which there is little aerial mycelium and profuse development of falcate conidia typical of those found on the host in nature. The sporulating character usually remains constant during several successive single-spore transfers. Variations in temperature, light, vitamin content of media, reaction of media, carbon source, and nitrogen source have not affected the rate of appearance of sporulating sectors. When the mycelial and sporulating lines are grown together in test-tube cultures the former soon predominates, partly because of its greater growth rate.

A Pythium Tuber Rot and Wilt of Irish Potatoes. PERSON, L. H. A disease of Irish potatoes characterized by a sudden wilting of the plants and a rot of the tubers was found in the spring of 1941 in Louisiana. The outbreak occurred on Katahdin and Triumph varieties during a period of cool weather following a heavy rain. The tuber rot appeared to be distinct from "leak," the tuber being firm and its interior a smoky gray. Isolations from tubers yielded cultures identified as *Pythium debaryanum*. Inoculation of healthy tubers with these isolates produced a rot similar to that found in the field. At the same time inoculations were made with *Phytophthora erythroseptica*, which also occurs in Louisiana. Typical symptoms were obtained, indicating that the rot also was distinct from pink rot. This Pythium rot seems distinct from other rots reported in the United States and resembles in some respects a wilt caused by *Pythium butleri*, reported in Cyprus.

A Rapid Method for Mechanically Transmitting Plant Viruses. RICHARDS, B. LORIN, JR., AND HENRY M. MUNGER. Promising results have been obtained with a high-velocity spray stream in transmitting certain plant viruses. Diluted viruliferous juice, containing 300–400-mesh carborundum, was sprayed on plants through a suction-feed glass atomizer, fabricated of 5-mm. glass tubing, drawn to 0.5–1.0-mm. orifices. Best results were obtained when the atomizer was held 5 to 7 centimeters from the leaves and air pressure above 30 lb. was used. A tank of liquified carbon dioxide proved to be as satisfactory a source of pressure as compressed air and was particularly adaptable for field or greenhouse inoculations. A cut-off assembly (DeVilbiss No. 633) connecting the atomizer to the source of pressure greatly facilitated the spray applications. The method has been used with excellent results to transmit Bean Virus 4 and two strains of Bean Virus 1 to bean plants, and several strains of Cucumber Virus 1 to cucumber. Under direct comparison this spray technique gave percentages of infection as high as, or higher than, did the carborundum-rubbing method. Several thousand bean and cucumber plants were inoculated by spraying with their respective viruses in the field and greenhouse this past season. The results were more satisfactory and the time required was approximately one-fourth of that necessary when the rubbing method was used the previous summer.

Effect of Light Intensity on Infection Types Produced by Races 19, 38, 59, and 59A of Puccinia graminis tritici on Susceptible and Resistant Wheats. RODRIGUEZ V., JOSÉ. High light intensity was conducive to rapid and optimum development of races 19, 38, 59, and 59A on Little Club wheat and other susceptible varieties, with the production of type 4++ uredia. At low light intensity the infection type may be reduced to type 3. All four races produce type 2 uredia on Marquis, but a distinct necrotic band is produced around the uredia under high light intensity, thus limiting the extent of mycelial development. At low light intensity, on the other hand, relative absence of necrosis permits the mycelium to grow more extensively and, although initial sporulation is depressed, secondary and tertiary crops of spores may be produced in diamond-shape bands along the

edges of infected areas, especially if light intensity is increased. This is true also of race 59A on Reliance. Likewise, races 38, 59, and 59A produce type X– infection on Kubanka durum under high light intensity and a somewhat higher infection type under lower intensity, because of the limiting effect of the more pronounced necrosis under the more intense light.

Negative Correlation Between Size of Crown Rust Pustules and Grain Yields in the New Oat Variety, Traveler. ROSEN, H. R. It commonly is assumed that size of pustule indicates degree of susceptibility and consequently is a measure of possible crop losses from cereal rusts. Consistent with this assumption, the oat variety Victoria is considered resistant to common races of crown rust because pustules are usually smaller on this variety than on susceptible varieties. The variety Traveler (Victoria × Custis) was selected because when infected by crown rust it shows a minimum of leaf injury although the pustules are larger than are those on its rust-resistant parent, Victoria. When approximately the same amount of inoculum is applied to Victoria, Traveler, and a susceptible selection from the same cross, the susceptible type has about 10 times as many infections. Killing of leaf tissue is faster in Victoria and Traveler, but the amount of dead or injured tissue is eventually far greater in the susceptible type and apparently proportionate to the number of infections. For five years Traveler has yielded as well as, or better than, other Victoria hybrids with smaller pustules, including sister selections from the same cross. This seemingly suggests that in evaluating susceptibility, size of pustules is not so important as number of infections and amount of leaf tissue injured.

Seedling Blight and Root Rot of Flax in Washington. SCHUSTER, MAX L., and E. J. ANDERSON. Seed coat injury due to threshing, and attack by soil-borne fungi were responsible for poor stands of flax in Washington. Samples of seed varied in the amount of seed with broken coats from 10 to 15 per cent for Zenith and Redwing to 65 to 75 per cent for Viking and Bison. In greenhouse trials, seed threshed by hand produced better stands than did seed threshed by machine at medium cylinder speed. Seed threshed at high cylinder speed produced the poorest stand. Field trials with seed lots threshed by the three methods showed highly significant differences in seedling emergence. *Fusarium oxysporum* Schl. was obtained most frequently in isolations from flax seedlings. Pathogenicity tests showed it to be virulent and the principal pathogen involved in decreased flax stands in Washington. The tests showed also that saprophytic organisms such as *Alternaria* and *Penicillium* may reduce stands. Flax stand was improved by the use of Spergon, New Improved Ceresan, Dubay 1205 FF (50 per cent tetramethyl thiuramdisulfide), and Semesan in greenhouse tests. The first three compounds were equally effective in protecting the seed sown in the field. These treatments produced much greater increases in stands from machine-threshed seed than from hand-threshed seed.

Preliminary Results on the Effectiveness of Elgetol as an Eradicant in Grape Black-rot Control. SHAY, J. RALPH. In a preliminary trial during the 1944 season 1 per cent Elgetol at the rate of 400 gal. per acre was applied to the ground of a one-acre Concord vineyard. The vines were treated with 0.5 per cent Elgetol, 150 gal. per acre. The application was made in the spring after the ascospores of the black-rot fungus had matured but before bud break. An adjoining 2-acre vineyard was used as a control. A measurement of the number of ascospores discharged from mummies collected from the ground in the treated vineyard before and after the Elgetol was applied showed 95.5 per cent suppression of ascospore discharge by the eradicant. Counts of black rot on fruit in late June showed a much reduced level of infection in the eradicant-treated vineyard. Plots in the eradicant-treated vineyard which received no protectant sprays showed about the same amount of infection as plots in the control vineyard which received a full protectant spray program. Fermate gave as satisfactory control in the eradicant-treated vineyard as did Bordeaux 6–8–100 or 3–4–100. No deleterious effect of Elgetol on vigor of the vines could be discerned.

Immunization of Peach Trees to X Disease by Chemotherapy. STODDARD, ERNEST M. Seedling peach trees in pot culture, inoculated with X disease by budding, were injected with chemicals through the cut upper end of the main stem. In 124 trials, *p*-aminobenzenesulphanilamide at various concentrations and under various conditions reduced infection to 21 per cent. At a concentration of 1–2000 injected after inoculation, it completely prevented infection of 45 trees. Check inoculations averaged 85 per cent infection. Maltose or dextrose combined with *p*-aminobenzenesulphanilamide antidoted to a considerable degree its injurious effect on the trees without antidoting its effect on the virus. *p*-Aminobenzoic acid completely antidoted the effect of *p*-aminobenzenesulphanilamide on the virus, just as it antidotes the bactericidal and fungicidal properties. *p*-Toluenesulphanilamide was less effective and less phytotoxic than *p*-aminobenzenesulphanilamide. Hydroquinone, maltose, dextrose, and zinc sulphate reduced infection considerably. It is significant that *p*-aminobenzenesulphanilamide had no therapeutic value in the inactivation of the virus in diseased buds, but that hydroquinone was somewhat effective. With

the exception of zinc sulphate, all the chemicals were more effective when injected two weeks after inoculation than when injected two weeks before inoculation. It is suggested that the inhibitory effects of the chemicals on the virus of X disease is due to artificial immunization.

Experimental Immunization of American Elm from Infection by Verticillium albo-atrum. TEHON, L. R. Immunization of American elm from artificial infection by *Verticillium albo-atrum* appears to have followed injection of staled culture medium and mycelial extract. The fungus was grown on a liquid medium for 10 days and then separated with a Berkefeld candle. This staled medium was used without alteration. The mycelial mat was ground in quartz sand and extracted with water, and the extract was separated with a Berkefeld candle. In August, eight trees 1½ inches in trunk diameter were established in the greenhouse and maintained for two years. In April, by injection, two trees were given staled medium and two trees were given mat extract. In October, November, and January, six trees were given heavy spore injections. By April 1, in the two inoculated check trees there was a general wilting; the fungus was reisolated from them then and in July and in August. The two trees which received injections of staled medium or mat extract, but no spores, exhibited pronounced "anaphylactic" reactions but no wilting. The two trees which received injections of staled medium or mat extract, and spores, did not wilt, and attempts made in April, July, and August to reisolate the fungus from them failed.

Loss Incident to Sprouting among Stored Potatoes Reduced by Hormone Treatments. THOMAS, JOHN E., AND A. J. RIKER. During the warm spring weather any potatoes left in storage have commonly sprouted and soon become worthless. Such sprouting has been prevented by hormone treatments and the selling season has been extended. Among several chemicals tried, the methyl ester of alpha-naphthaleneacetic acid was most successful. It was effective with small variations for the inhibition of sprouting on all varieties tried, *viz.*, Chippewa, Cobbler, Russet Burbank, Russet Rural, Red Warba, and Triumph. Applications of approximately 0.9 gm. per bushel in dilute alcohol or lanolin emulsion sprays, in talc or walnut-shell flour dusts, or on impregnated shredded paper were all effective. Trials were begun in January or February and were run from two to four months at about 70° F. In all cases the checks sprouted and became worthless, many of them rotted. The treated tubers lost some water, but even after several months in warm storage, were still marketable. The treatment became progressively less effective with time. Four to six weeks after treatment Cobbler tubers developed a hard, knobby type of outgrowth, usually in the bud area. In severe cases this growth cracked open.

Seedling Diseases of Sugar Beets in Ohio. TILFORD, PAUL E., AND H. C. YOUNG. Seedling diseases are the principal cause of poor stands of sugar beets in Ohio. *Aphanomyces cochlioides* is responsible for the major loss. Disease caused by *Rhizoctonia* sp. is less common but sometimes very severe. Injury from *Phoma betae* and *Fusarium* sp. occur to a minor degree. The use of high phosphate fertilizers in the row at planting time usually has reduced seedling diseases in the field on soils which have received a liberal application of manure. In greenhouse experiments, row application of either 20 per cent phosphate or complete fertilizer has reduced the Aphanomyces disease but has had little or no effect on diseases caused by the other organisms. Increasing the PO_4 content of culture media from 190 to 9000 ppm. had no retarding effect on growth of *A. cochlioides.* Increasing the concentration of a modified Hoagland solution, to which soybean extract had been added, from 0.8 atmosphere to 2.8 atmospheres had no effect on the growth rate of *A. cochlioides.* When beet seedlings were grown in gravel, inoculated with corn-meal cultures of *Aphanomyces* and irrigated with the same solution minus the soybean extract, seedling loss decreased as the concentration increased from 0.3 atmosphere to 3.78 atmospheres.

Can Tobacco Blue-mold Fungus be Eradicated? VALLEAU, W. D. Although blue mold of tobacco was general in the Georgia-Florida area from 1931 on, it was prevalent throughout the Tennessee-Kentucky tobacco area for the first time in 1937, indicating that this area is not in the direct line of spread of spores from the Georgia area. Since 1937 blue mold has become less and less prevalent until in 1944 only 2 cases were observed or reported in the Tennessee-Kentucky area. This suggests that the blue-mold fungus is not capable of maintaining itself indefinitely north of the Georgia-Florida area. Eradication of overwintering living plants and the use of new plant-bed sites in the Georgia-Florida area should result in the complete eradication of the fungus from the eastern tobacco-growing areas of the United States in a relatively short time.

Progress in Combination of Yellows and Mosaic Resistance with High Ascorbic Acid Content in Cabbage. WALKER, J. C. Wisconsin All Seasons cabbage is heterozygous for the major gene for resistance to yellows (*Fusarium oxysporum f. conglutinans* (WR.) S. and H.). By selection, homozygous resistant lines of improved type have been isolated.

These lines have been artificially inoculated with the cabbage mosaic viruses (a strain of *turnip virus 1* and a strain of *cauliflower virus 1*). Lines highly resistant to mosaic have been isolated. Within these, lines with 60 mg. or more of ascorbic content per 100 gm. of fresh tissue acid have been secured. With increase of the latter a new strain of Wisconsin All Seasons variety will be available which is homozygous for resistance to yellows, highly resistant to mosaic, and relatively high in ascorbic acid content. (University of Wisconsin and U. S. Dept. of Agriculture.)

A Major Gene for Resistance to Near-wilt in Pea. WALKER, J. C., E. J. DELWICHE, AND W. W. HARE. All commercial varieties of pea resistant to wilt (*Fusarium oxysporum* Schl. f. *pisi* (Linf.) *race 1* S. and H.) are susceptible to near-wilt (*F. oxysporum* Schl. f. *pisi* (Linf.) *race 2* S. and H.). While a degree of tolerance has been attained by selection from certain varieties, such resistance is complex genetically and not readily fixed. In a single plant line from a cross between two varieties, Admiral and Pride, neither of which are tolerant to near-wilt, a major gene for complete resistance has been isolated. This behaves as a dominant to near-wilt susceptibility. The F_2 progenies of a cross with Wisconsin Perfection (resistant to wilt but very susceptible to near-wilt) fit closely the ratio of 1 resistant: 2 segregating: 1 susceptible. Having this line as a breeding parent, the major genes for wilt and near-wilt are being combined with desirable canning and garden varieties.

Seed and Seedling Infection of Barley, Bromus inermis, and Wheat by Strains of Xanthomonas translucens. WALLIN, JACK R. Strains of *Xanthomonas translucens* reduced seedling emergence from artificially infested *Bromus inermis*, barley, and wheat seeds planted on moistened filter paper in Petri dishes or in steamed soil in the greenhouse. Hulling barley had a greater effect on the amount of seedling infection than did the period of soaking in the brome strain of *Xanthomonas translucens*. Wounding the embryos not only lowered germination of the checks, but also gave rise to a larger percentage of infected seedlings in the infested series. Infested hulled barley in comparison with infested unhulled barley planted in steamed soil gave significantly lower emergence and greater numbers of diseased seedlings. The barley, brome, rye, and wheat strains caused seedling infection of barley and wheat, but only the brome strain infected seedlings of *Bromus inermis*. The emergence of the seedlings from wounded and hulled seeds infested with the four pathogens was reduced over the check. The temperature during germination, rather than the temperature at which the seeds were soaked, was the important factor in emergence reduction of barley. Lesions were apparent on seedling coleoptiles within 48 hours. Freehand and paraffin sections showed the bacteria to have infected the coleoptile and the adjacent first foliage leaf. The inner leaves were not invaded at this period.

Host Relation of Xanthomonas translucens. WALLIN, JACK R. A bacterium isolated from the translucent streaks occurring on brome grass leaves was pathogenic on *Bromus inermis*, barley, oats, rye, and wheat causing symptoms on the leaves, leaf sheaths, and culms identical with those caused by one or more strains of *Xanthomonas translucens*. In cross-inoculation studies the brome grass and wheat bacterial strains were pathogenic on Erban oats, *Bromus catharticus*, *Hordeum vulgare*, *Secale cereale*, and *Triticum aestivum*, and in addition, the brome strain was pathogenic on Boone oats, *Bromus carinatus*, *B. erectus*, 7 strains of *B. inermis*, and *B. marginatus*. In a comparison of the pathogenicity of the barley, brome, rye, and wheat strains of *Xanthomonas translucens* inoculated hypodermically into *Bromus inermis*, wheat, Boone and Erban oats, and Peatland and Velvet barley, the brome grass and the barley strains were pathogenic on *Bromus inermis* while the wheat and rye strains were not. All strains were pathogenic on barley, wheat, and Erban oats, while only the barley strain was strongly pathogenic on Boone oats. When the pathogens were sprayed on the leaves, the brome and barley strains were pathogenic on *Bromus inermis* but not on wheat, while the wheat and rye pathogens were pathogenic on barley and wheat. The strains used in these studies do not fit the descriptions of the *formae speciales* for *Xanthomonas translucens*.

A New Dust with Adherence. WATSON, R. D., AND A. A. NIKITIN. One of the chief limiting factors of fungicidal dusts in general is their low adhesiveness. In earlier tests various oils were used but mixtures proved inferior to the standard dust. The new dust mixture is essentially the same as the standard copper 10 per cent – sulphur 90 per cent dust, excepting that 20 per cent clay is added to aid in the dispersion and absorption of 2 per cent oil. The main problem in adding oil was to procure a uniform distribution throughout the dust, which was accomplished by atomizing the oil into the blended dust so that there was no caking even when the oil was used at a concentration higher than that required for improved adhesiveness. It is essential to use a phytonomic (highly sulphonated) oil to avoid copper injury. Solubility tests show that fixed copper fungicides are not affected by the presence of this oil. The distribution of this new dust is more uniform and there is a better coverage on the foliage with less dust than with the standard material. Most important, field and laboratory tests show that it sticks. There

was an evident residue on leaves following more than 3 inches of rain. Tests also indicate that oil tends to minimize the separation of dust into active and inactive ingredients during its application.

A Greenhouse Weathering Technique for Predicting Field Performance of Fungicides. WELLMAN, R. H., AND S. E. A. MCCALLAN. Certain factors in weathering fungicidal deposits on field foliage are: rain, sunlight, wind, leaf growth and excretions, and humidity. Previous greenhouse weathering tests have been essentially rain tests. Significant performance differences were not obtained with Bordeaux and Spergon, even after 5 inches of laboratory rain. The above factors were studied separately and in combination by the "greenhouse tomato" method (Contrib. Boyce Thompson Inst. **13**: 93, 1942) and the following technique was developed. The fungicide is sprayed on 4-inch plants, which are returned to the greenhouse. Four times, at 3-day intervals, the plants are subjected to 100 per cent humidity for 16 hours, followed immediately by 0.5 inch of laboratory rain. The plants are then inoculated and later disease readings made. The effect of weathering can be evaluated by comparison with results obtained simultaneously on unweathered plants. Controlling (LD95) late blight on unweathered plants takes approximately: Spergon and Fermate, 0.3 lb. per 100 gallons; Bordeaux mixture, 1.5 lb. (as copper sulphate). After weathering the same control requires: Bordeaux mixture, 4 lb.; Fermate, 8 lb.; while Spergon at 8 lb. gave no appreciable control. This method has been used successfully in selecting compounds for field tests on late blight and apple scab.

The Zinc Salt of Dimethyl Dithiocarbamic Acid (Methasan and Zincate) as a Fungicide on Vegetables. WILSON, J. D. This material has compared favorably with copper, sulphur, and various organic fungicides in the control of the early blights of potato, tomato, and celery, and the anthracnose fruit rot of tomato.

Summary of Results Obtained in a 10-State Experiment on the Control of Tomato Anthracnose. WILSON, J. D., AND H. A. RUNNELS. This experiment included Fermate and Tribasic copper sulphate used alone and in an alternating schedule for the control of anthracnose fruit rot. Pathologists in Maryland, New Jersey, Delaware, Connecticut, Pennsylvania, New York, Ohio, Illinois, Michigan, and South Dakota applied the same formulas in the same schedule to artificially inoculated plots. The disease was scarce in most of the states included in the test, chiefly because of lack of rainfall in late July and August. It occurred in sufficient quantity in many of the inoculated plots, however, to indicate that Fermate may be expected to give a definite reduction in the number of affected fruits.

Puratized N5D, Fermate, and Methasan for the Control of Apple Scab and Bitter Rot. WINTER, H. F., AND H. C. YOUNG. In 1944 orchard tests at Wooster, Puratized N5D (22 per cent), ½ pint per 100 gallons of water, excelled all other treatments in the control of apple scab. Fermate and Methasan gave somewhat less control of scab than the standard Flotation Sulphur schedule. In previous years (1942–1943), however, Fermate was the equal of Flotation Sulphur for scab control. Puratized N5D at the same strength gave perfect control of bitter rot on Grimes in southern Ohio in 1944, whereas Fermate, 2 lb. per 100, and Bordeaux 4–6–100 each reduced the rot to 0.5 per cent. Methasan plus a wetting agent failed to control bitter rot satisfactorily in this experiment. The standard 4–6–100 Bordeaux generally used for bitter-rot control caused excessive foliage and fruit injury. All three organic materials used gave excellent fruit size and finish and caused no perceptible injury on Grimes. Apples sprayed with the Bordeaux averaged 347 to the bushel while those sprayed with the organic materials averaged only 207.

Factors Influencing the Development of Ceratostomella ulmi in Elm Trees. ZENTMYER, GEORGE A., AND PHILLIP P. WALLACE. Nutritional and anatomical differences in elm wood and dosage and age of fungus spores are important factors influencing initiation and development of the Dutch elm disease. Extracts of current season's wood supported much better *in vitro* growth of *C. ulmi* than did extracts of previous season's wood, indicating nutritional variations in different-aged woods. Rapid disease development following early season (May-June) inoculations apparently results from a combination of favorable nutritional substrate and presence of wide rings of large spring vessels. Trees which had been defoliated in June by cankerworms (*Alsophila pometaria* and *Paleacrita vernata)* were much more severely affected than non-defoliated trees when inoculated with *C. ulmi*, possibly because of a prolongation of spring wood formation. Trees which responded vigorously to fertilization with several N sources were not so susceptible to the disease, indicating alterations in nutritional character of wood and sap stream. Severity of disease development increased directly with the number of spores with which trees were inoculated. With an equal number of spores per tree, infection was more severe with multiple inoculation points than for a single point of inoculation. For example, 10 inoculations of 100 spores each were more effective than 1 inoculation of 1000 spores. Old spores were less effective than young spores in producing disease.

EFFECT OF SPRAY INJURY ON PRE-HARVEST DROP OF McINTOSH APPLES[1]

F. H. LEWIS[2]

(Accepted for publication April 8, 1944)

Dutton[3] reported in 1932 that pre-harvest drop of Jonathan, Hubbardston, and Baldwin apples varied with the fungicide used in fungicide-lead arsenate sprays. Lime-sulphur caused more pre-harvest drop than Bordeaux mixture. The largest and most consistent differences were obtained when there was a moderate to full crop of fruit. Mills[4] obtained similar differences between lime-sulphur and elemental sulphur on McIntosh in 1935 and 1937.

Lime-sulphur causes considerable leaf injury when used in summer sprays on apple and the amount of pre-harvest drop seems to vary with the extent of leaf injury. Evidence concerning this relationship is presented in this paper.

PROCEDURE

This experiment was conducted in Wayne County, New York, in 1942, with 20-year-old McIntosh apple trees growing in sod. They were in moderate vigor, reasonably uniform in size, and had received uniform treatment for at least the two previous seasons.

Six spray schedules were followed on 7 single-tree plots in randomized blocks for each schedule. Two pre-blossom and 6 post-blossom applications were made at approximately 12-day intervals. Each tree received about 10 gallons of spray in each application; and all spraying was from the top of the sprayer tank with an 8-nozzle boom.

Leaf-injury data were obtained on the leaves of spurs that bloomed in 1942 but failed to set fruit. Forty spurs per tree, taken around the tree at a height of 4 to 6 feet, were used in each instance.

A leaf-injury index was calculated with the object of expressing in one figure both the amount of visible leaf injury on the spur leaves when the counts were made and the amount of leaf fall which had occurred prior to the counts. This was accomplished by the use of classes based on the degree of injury, with the assignment to each class of numerical value; the highest values corresponded with the greatest injury. It was necessary to

[1] An abridgement of one section of a dissertation submitted to the Faculty of the Graduate School of Cornell University, February, 1943, as a major thesis in partial fulfillment of the requirements for the degree Doctor of Philosophy.

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The author wishes to acknowledge his appreciation to Drs. A. B. Burrell, L. M. Massey, and W. D. Mills for their many helpful suggestions and criticisms during this study.

[3] Dutton, W. C. Spray injury studies. 2. Secondary effects of spray injury to apple foliage. Mich. Agr. Exp. Stat. Spec. Bull. 219. 1932.

[4] Unpublished data of Dr. W. D. Mills, Department of Plant Pathology, Cornell University, Ithaca, New York.

assume a base number of leaves before leaf fall began, an assumption which proved to be unjustified. Therefore, an effective-leaf-surface index was calculated as follows: number of healthy leaves $\times 5$, number of leaves with slight marginal necrosis and up to 25 per cent of the margin killed $\times 4$, number of leaves with 25 to 50 per cent of the margin killed $\times 3$, number of leaves with over 50 per cent of the margin killed $\times 2$, and number of yellow leaves $\times 1$. Thus the effective-leaf-surface index is the negative of a leaf-injury index.

The fruits that dropped were picked up at intervals in September and records made of their total number and the number entered by codling-moth larvae. Similar data were obtained on each of two representative crates of picked fruit per tree; and the number of crates of picked fruit was secured. All calculations concerning the fruit were based on these data. All percentages are percentages of the total number of fruits per tree in late August before pre-harvest drop began.

The data were treated statistically by the analysis-of-variance and analysis-of-covariance methods as outlined by Livermore[5] and Snedecor.[6]

RESULTS

The use of lime-sulphur without an insecticide in the pre-blossom and calyx sprays caused a small amount of marginal necrosis and considerable leaf deformity of the type commonly associated with the use of lime-sulphur on immature apple leaves. However, injury did not become severe until Mid-July (Table 1) and was first evident as one or more small dead areas on the leaf margin, often at the leaf tip. These areas enlarged in the more severe cases until a band of dead tissue more or less surrounded a central green area. This central area often became yellow and the leaf fell. Some leaves yellowed and fell without necrosis. The writer believes that the injury after Mid-July was due primarily to arsenic.

The leaf injury varied in severity and time of appearance with the spray treatment. Trees sprayed with lime-sulphur in the cover sprays, with or without lead arsenate and lime, had considerable leaf injury in July. With lime-sulphur alone (Schedule 1), the amount of injury increased in August with little further increase in September. With lime-sulphur and lead arsenate (Schedule 2) or with lime-sulphur, lead arsenate, and lime (Schedule 3), the amount of injury increased in August and September. With flotation-sulphur paste, lead arsenate, and lime (Schedule 4) or with lead arsenate and lime (Schedules 5 and 6), most of the injury occurred in September.

The pre-harvest drop began the last week in August when the majority of the apples were about two inches in diameter. The cumulative percentage fruit drop and other harvest data are in table 2.

Lime-sulphur, lead arsenate, and lime in the cover sprays caused a highly significant increase in pre-harvest drop over lime-sulphur alone; lead arse-

[5] Livermore, J. R. Laboratory exercises in statistical methods of analysis. (Mimeographed.) Cornell University, Department of Plant Breeding. 1939.

[6] Snedecor, G. W. Statistical methods. 422 pp. The Iowa State College Press. 1940.

TABLE 1.—*Leaf injury on McIntosh apple trees by fungicide-insecticide combination sprays*

Spray schedule[a]			July 22 counts				October 1–4 counts				
				No. leaves per spur with part margin dead				No. leaves per spur with part margin dead			
Pre-blossom sprays	Calyx spray	Cover sprays	No. leaves per spur	Up to 25 per cent	Over 25 per cent	Effective-leaf-surface index	No. leaves per spur	Trace to 25 per cent	25 to 50 per cent	Over 50 per cent plus yellowing	Effective-leaf-surface index
1. Flotation sulphur	Flotation sulphur Lead arsenate Lime	Lime-sulphur	8.21	1.87	0.10	38.89	6.65	2.12	0.56	0.29	29.05
2. "	"	Lime-sulphur Lead arsenate	8.11	2.23	0.14	37.89	5.83	2.13	1.13	0.92	21.88
3. "	"	Lime-sulphur Lead arsenate Lime	8.14	2.01	0.20	38.01	5.57	1.93	1.55	1.45	18.40
4. "	"	Flotation sulphur Lead arsenate Lime	8.44	0.21	0.02	42.36	6.75	2.47	0.71	0.29	28.89
5. "	"	Lead arsenate Lime	8.53	0.17	0.04	42.31	6.27	2.65	0.54	0.22	26.84
6. Lime-sulphur	Lime-sulphur	Lead arsenate Lime	8.49	0.60	0.04	41.78	6.31	2.58	0.82	0.39	26.12
Least mean difference for odds of 19:1			0.29	0.58	0.09	1.76	0.41	0.37	0.26	0.33	2.60
99:1			0.39	0.78	0.12	2.37	0.55	0.50	0.36	0.45	3.50

[a] Flotation sulphur paste of the Thylox type obtained from the Rochester Gas and Electric Company, Rochester, New York. Lime-sulphur solution testing 32 to 33° Baumé, NuRexForm acid lead arsenate, and hydrated spray lime obtained from the Sodus, New York, branch of E. I. Du Pont de Nemours and Company. Flotation sulphur paste was used at 8 pounds, lime-sulphur at 2 gallons, and lead arsenate and lime at 3 pounds, in 100 gallons of spray. The order of mixing was the fungicide followed by lime followed by lead arsenate.

TABLE 2.—*Effect of sprays on pre-harvest drop of McIntosh apples*

Spray schedule[a]			Total No. fruits per tree	Cumulative drop as per cent of the total fruits per tree				Drop due to codling moth injury. Per cent total fruits	Picked fruit	
Pre-blossom sprays	Calyx spray	Cover sprays		Sept. 2	Sept. 16	Sept. 22	Sept. 30		Per cent total fruits	Crates of 1.2 bushels
1. Flotation sulphur	Flotation sulphur Lead arsenate Lime	Lime-sulphur	1886	6.65	12.68	16.23	29.27	22.56	48.17	6.8
2. "	"	Lime-sulphur Lead arsenate	1639	5.18	13.37	19.10[b]	31.13	4.92	63.95	8.4
3. "	"	Lime-sulphur Lead arsenate Lime	1844	5.17	16.00	24.78	47.18	5.47	47.35	6.3
4. "	"	Flotation sulphur Lead arsenate Lime	1759	5.08	9.75	13.00[b]	24.24	4.81	70.95	9.3
5. "	"	Lead arsenate Lime	1889	4.26	7.79	9.71	19.54	5.71	74.75	11.0
6. Lime-sulphur	Lime-sulphur	Lead arsenate Lime	1774	5.13	10.37	12.73[b]	21.11	7.74	71.15	10.5
Least mean difference for odds of 19 : 1 99 : 1			[c]	.....	3.34 4.49	.....	7.40 9.96	.....	.....	2.5 3.4

[a] See description of materials and concentrations in footnote to table 1.
[b] Sprayed September 17 with "Parmone" at 1 pint to 100 gallons of spray. The active ingredient in "Parmone" is naphthalene acetic acid.
[c] The differences in total number of fruits per tree are not mathematically significant.

nate and lime; and flotation-sulphur paste, lead arsenate, and lime. The data indicate that a heavy hormone application on September 17 was not of sufficient value to overcome the effects of the lime-sulphur spray mixtures. Perhaps the hormone sprays are less effective in reducing pre-harvest drop when the leaves have been previously injured by spray materials.

Since both leaf injury and pre-harvest drop varied with the spray treatment and both were greatest where lime-sulphur was used in the cover sprays, a covariance analysis of the data was used to determine the degree of association between these two variables. Covariance analysis of the effective-leaf-surface index on October 1 and the percentage fruit drop up to September 30 showed a highly significant negative correlation of -0.622. There were highly significant differences between treatments after correction for the "effective leaf surface" on October 1. The data suggest that, in addition to the amount of visible leaf injury on October 1, the fruit drop was affected by the time the injury occurred, the effect of the sprays on leaf efficiency, and the hormone spray applied to 21 of the 42 trees in the experiment.

DISCUSSION

The association between leaf injury and pre-harvest drop shown by the correlation coefficient obtained in this experiment is somewhat obscured by such variables as the use of the hormone spray on part of the plots. It is believed that the excessive dropping of uninjured fruits from these trees can be explained almost entirely on the bases of the amount of visible leaf injury, the time the injury occurred, and the effect of the sprays on leaf efficiency.

The dropping of McIntosh apples before they attain an acceptable degree of maturity and a red color is one of the major faults of the variety. The data presented indicate that the present trend toward the elemental sulphur fungicides will result in less serious losses from pre-harvest fruit drop and perhaps decrease the number of cases where a hormone spray will be needed.

SUMMARY

Under uniform cultural conditions, the amount of visible leaf injury and pre-harvest drop of McIntosh apples varied significantly with the spray treatment. Covariance analysis showed a highly significant correlation between leaf injury and pre-harvest drop. Both were greatest on trees sprayed with lime-sulphur, lead arsenate, and lime in the cover sprays. Flotation sulphur, lead arsenate, and lime in the cover sprays caused less leaf injury in July and August and less pre-harvest fruit drop than lime-sulphur, lead arsenate, and lime.

The thesis is advanced that the excessive dropping of uninjured fruits from these trees can be explained on the bases of the amount of visible leaf injury, the time of injury, and the effect of the sprays on leaf efficiency.

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PHYSIOLOGIC SPECIALIZATION OF PUCCINIA GLUMARUM ERIKSS. AND HENN. IN CHINA[1]

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(Submitted for publication April 6, 1944)

INTRODUCTION

In a number of wheat growing regions in China, severe losses are sustained annually through stripe rust, a disease caused by *Puccinia glumarum* Erikss. and Henn. It is now almost universally accepted that the most effective and practical method to combat this disease is by breeding or selection of resistant varieties that also are desirable in agronomic characters (2, 4, 12). Before a breeding program to cope with this disease can be effective, however, data should be available on the number of physiologic races of rust present and the reactions of varieties of wheat to those races. In the present paper, the writer brings together the results obtained in determining physiologic races of *Puccinia glumarum* Erikss. and Henn. in Yunnan, China. Data are presented on the reactions of certain highly resistant varieties that are valuable for breeding experiments.

EARLY WORK

In 1894 Eriksson (5) first recognized 5 specialized varieties of *Puccinia glumarum*. They were *Puccinia glumarum tritici* on wheat, *P. glumarum hordei* on barley, *P. glumarum secale* on rye, *P. glumarum elymi* on *Elymus arenarius*, and *P. glumarum agropyri* on *Agropyron repens*. From the later investigations of Hungerford and Owens (10), Gassner and Straib (7, 8, 9) and others (11, 13, 14), it is known that *P. glumarum* comprises many physiologic races and that they are not so narrowly restricted in host range as Eriksson once thought.

The existence of physiologic races in *P. glumarum* was first suggested by Hungerford and Owens in 1923 (10). They found that *Bromus sterilis* was resistant to the rust from *Hordeum jubatum* but susceptible to rust from *Bromus marginatus* and *Elymus glaucus*. It was possible that two strains of *Bromus sterilis* were used or that two races of the rust were involved. Rudorf (12) in his studies on the reactions of 29 wheat varieties to 25 collections of *P. glumarum* from different parts of Europe, found that the races of rust occurring in Europe might be distinct from those in the United States. A year later, in 1930, 4 races were differentiated on 6 varieties of wheat by Allison and Isenbeck (1); and about the same time, 2 distinct

[1] Paper No. 19 from the Division of Plant Pathology, Institute of Agricultural Research, National Tsing Hua University. This investigation was conducted in cooperation with the National Agricultural Research Bureau, Ministry of Agriculture and Forestry. The writer wishes to express his indebtedness to Dr. T. F. Yu for suggestions during the progress of the work and to Prof. F. L. Tai for reading the manuscript.

Phytopathology extends the courtesy of its journal pages to scientists in other countries who are persevering in research under difficult wartime conditions and are temporarily deprived of the opportunity for membership in the American Phytopathological Society.

races in the main wheat growing regions of Western Germany were reported by Gassner and Straib (7). Extensive surveys on physiologic races of this rust have since been made in Europe, United States, and Canada, and at the present time more than 50 races have been identified (3, 11, 13, 14, 15).

MATERIALS AND METHODS

The investigations were made in the greenhouse each year from December to the end of April, in Yunnan, China. The fungus is extremely sensitive to high temperatures, so precautions were taken to keep the temperature below 25° C. by proper shading and ventilation. Seedlings at the two-leaf stage were inoculated after the method of Hungerford and Owens by spreading the fresh uredospores on the upper leaf surface with a scalpel. After inoculation, plants were incubated in moist chambers for 48 hours and then transferred to benches in the greenhouse. The stock cultures, originating from a single sorus, were kept under lamp chimneys covered with a layer of cotton wool to prevent contamination.

The differential hosts used in these experiments included those used by Gassner and Straib,[2] and certain other wheat varieties. Most of the rust collections were made by the writer in Yunnan. Only 6 of the 54 collections studied came from other sources.

The classification of the infection types and host reaction is the one given by Hungerford and Owens (10) with the addition of the immune reaction of Gassner (See 9). Six infection types are thus distinguished: i, 0, 1, and 2 in the resistant class; and 3 and 4 in the susceptible class.

IDENTIFICATION OF PHYSIOLOGIC RACES IN CHINA

In the spring of 1941, 11 collections of the rust, 9 from Yunnan Province and 2 from Szechwan Province, were inoculated on 10 available differential varieties used by Gassner and Straib (See 9), (Bon Fermier, Carsten V, Chinese 166, Heines Kolben, Michigan Amber, Rouge Prolifique Barbu, Strubes Dickkopf, Vilmorin 23, Webster, and Heil's Franken). The results indicated marked differences in the reactions of some hosts to the rust collections. Some of these hosts, however, grew poorly under local field conditions or were of little value as differential hosts for the Chinese rust collections. Ten other varieties, selected from varietal resistance tests in China, were tested as differential hosts, so that a total of 20 varieties were available for further study. Some of the 20 varieties proved not to be differential hosts when inoculated with different collections of the rust; and eventually only 8 of them were chosen as the standard differential hosts: Carsten V, Heines Kolben, Vilmorin 23, Heil's Franken, 9 H 77, Hybrid 128, Carina, and Michigan Amber. Heil's Franken is a barley and 9 H 77 is a common wheat (*Triticum vulgare* Host. var. *ferrugineum* Körn.) from Percival's world collection.

[2] Thanks are due Dr. H. Becker of Halle University, Germany, for sending us seeds of these differential hosts.

It is important to point out here that the variety "Chinese 166," one of the differential hosts used by Gassner and Straib, is well known as immune from or highly resistant to most races of stripe rust in Europe and other countries. It was discarded as a differential host by the writer because it was extremely susceptible to all rust collections in China. It seems probable that the races indigenous to China are different from those in other countries.

Up to the spring of 1943, 9 physiologic races from 43 collections of the rust have been differentiated on the 8 host varieties. The distribution of these 9 races and the infection types they produce on the 8 host varieties are in table 1.

In general, there was a high degree of consistency in the infection type produced by each race, and the types recorded in table 1 are based on 4 or 5

TABLE 1.—*Distribution in China and types of infection produced by 9 physiologic races of Puccinia glumarum on 8 different hosts*

Source and number of rust collections	Infection type on differential hosts								Race designation
	Carsten V	Heines Kolben	Vilmorin 23	Heil's Franken	9 H 77	Hybrid 128	Carina	Michigan Amber	
Kunming—6	4	4	4	i	3–4	3–4	3–4	4	C 1
Chenkung—1	3–4	0	4	i	0	0	2–3	4	C 2
Kunming—18 Paoshan—1 Chenkung—3	0	4	4	i	3	3–4	3	4	C 3
Chengtu—2 Yungchiang—2 Mafong—1	2–3	4	0	i	0	0	4	4	C 4
Tunghai—1 Huaning—1	3	3	3	i	0	2–3	0	4	C 5
Pohsi—2 Hohsi—1 Tunghai—1	3	0	0	i	3	3	0	4	C 6
Pohsi—1[a]	i	i	i	4	i	i	i	4	C 7
Kunming—1	3	3	3	i	0	0	i	4	C 8
Kunming—1	0	0	3	i	0	3	3–4	4	C 9

[a] This rust was collected on barley, whereas all other collections were from wheat.

tests. Since these 9 races are not identical with any of the known ones, they are prefixed with the letter "C" to avoid confusion with the numbered races already reported by others.

Race C 1 is by far the most virulent and it differs from race C 3 in producing type 4 infection on Carsten V. Race C 7, collected from barley in the southern part of Yunnan, produced type 4 infection on Heil's Franken but failed to infect any of the wheat varieties tested except Michigan Amber, a variety highly susceptible to all 9 races. On the other hand, none of the races originating from wheat could infect Heil's Franken. Race C 7 therefore is distinct in its pathogenicity from the rest of the races. Nevertheless,

its ability to infect Michigan Amber makes invalid the strict separation of specialized varieties of *Puccinia glumarum* suggested by Eriksson.

Although the number of collections identified is too small to give precise data on the distribution of physiologic races in Yunnan Province, it is evident that race C 3 is by far the most prevalent in Kunming district, as it occurred in 18 of the 26 collections there. In second place is race C 1, identified in about one-fourth of the collections from Kunming district.

VARIETAL RESISTANCE

During four years, 1487 wheat varieties used in the program for breeding stripe rust and stinking smut resistant varieties for Yunnan were tested

TABLE 2.—*The infection types produced by races C 1 and C 3 of Puccinia glumarum on 30 resistant varieties of wheat*

Accession No.[a]	Variety	Origin	Infection type with C 1 and C 3
1 B 2	*Triticum monococcum* L. var. *vulgare* Körn.	U.S.S.R.	i–0
30 D 4	*T. dicoccum* Schubl. var. *rufescens* Perciv.	Abyssinia	0
2 E 15	*T. durum* Desf. var. *affine* Körn.	Spain	i–0
14 E 1	" var. *alexandrinum* Körn.	Spain	i–0
2 H 8	*T. vulgare* Host. var. *erythrospermum* Körn.	India	i
2 H 23	" "	Persia	0–2
6 H 3	*T. vulgare* Host. var. *Hostianum* Körn.	Canada	i
6 H 15	" "	Persia	i
8 H 2	" var. *erythrolencon* Körn.	India	0
9 H 23	" var. *ferrugineum* Körn.	Japan	i–0
9 H 66	" "	Portugal	i
9 H 102	" "	Argentina	i–0
9 H 125	" "	U.S.A.	i
9 H 166	" "	Moldavia	i–0
9 H 204A	" "	Poland	i–0
9 H 216	" "	Abyssinia	0–1
14 H 3	" var. *pseudo-barbarossa* Vav.	Persia	i
21 H 15	" var. *lutescens* Körn.	S. Africa	i
21 H 147	" "	England	i–0
21 H 156	" "	Canada	0
21 H 187	" "	England	0
21 H 189	" "	England	0–1
23 H 17	" var. *velutinum* Körn.	unknown	i
24 H 5	" var. *alboretum* Körn.	India	i–0
24 H 6	" "	India	0
24 H 14	" "	Australia	i–0
24 H 62	" "	Tibet, China	0
25 H 121	" var. *nigro-milturum* Körn.	Spain	0
26 H 19	" var. *delfii* Körn.	Iraq	0
8 K 3	*T. compactum* Host. var. *rubriceps* Körn.	China	i–0

[a] Accession number of Percival's collection.

for their reactions to races C 1 and C 3 of *Puccinia glumarum*. In general, none of the Chinese wheat varieties tested was resistant in the seedling stage. Many foreign wheats also were susceptible. There were, however, 30 varieties which were either immune from or highly resistant to the two races. These varieties together with their origin and the infection types produced by stripe rust races C 1 and C 3 are in table 2.

All but 2 of the 30 varieties resistant to races C 1 and C 3 were of foreign origin. It seems to the writer that the introduction of foreign material is indispensable for the breeding of stripe rust resistant varieties of wheat in China.

SUMMARY

Nine physiologic races of *Puccinia glumarum* were identified in 43 collections, most of them from Yunnan Province, China. Race separation was based on differences in infection type on seven varieties of wheat and one variety of barley. Races have been designated as races C 1 to C 9 inclusive.

Of 1487 varieties tested for their reactions to races C 1 and C 3 of *Puccinia glumarum*, 30 were either immune or highly resistant.

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DISTANCE AS A DOSAGE FACTOR IN THE SPREAD OF DUTCH ELM DISEASE

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(Accepted for publication June 1, 1944)

The dissemination of pathogenic fungi is influenced by many varied factors which are seldom subject to statistical analysis, either singly or in combination. The Dutch elm disease fungus [*Ceratostomella ulmi* (Schwarz) Buisman], however, provides an example of an organism whose dissemination can be studied statistically by establishing plots around isolated infected elms and determining spread outward from these centers.

This fungus is disseminated in the United States primarily by the smaller European elm bark beetle (*Scolytus multistriatus* Marsh.). The principal spread occurs when beetles emerge from dead or dying diseased elms and feed in the twig crotches of nearby healthy trees. Feeding is likely to be concentrated on elms in the vicinity of breeding wood. In the process of feeding, the beetles may inoculate elms with spores picked up from beetle galleries in the diseased elm wood from which they emerged.

This paper presents a study of this local intensification or "local spread" of Dutch elm disease on plots established under conditions of natural infection. Such data have two main applications:

1. The probabilities of infection occurring at varying distances from diseased elms have immediate and important application in local control measures. General statements have been made that local spread of the disease is usually not important beyond distances of from 300 to 500 feet, but no critical examination of this problem has been reported.

2. An opportunity is provided for determining the dose-response relations in dissemination of a pathogenic vascular fungus. Research in various fields of biology has shown that typically the response bears a linear relation to the logarithm of the dosage. This is true whether the response is measured as inhibition of germination of fungus spores when subjected to varying dosages of fungicide, or as disease response in relation to varying dosages of spores, or as response of experimental animals to doses of drugs.

Data by Dimond *et al.* (3) and Heald (6) furnish examples of application of the dose-response principle to plant pathology. Dimond *et al.* investigated extensively the relation between dosage of fungicide and response in incidence of disease or inhibition of spore germination. These factors show a rectilinear relation when plotted on logarithmic probability paper, indicating that the probit of the response varies directly with the logarithm of the dosage. Calculation of data given by Heald demonstrates that the percentage infection (as probits) for stinking smut of wheat increases with the logarithm of the number of spores on the grain.

In the present study, the "response" is measured in terms of numbers of newly infected elms, and the distance of the new infections from the

disease center constitutes the "dosage" factor, as it can be accurately measured while spore dosage cannot in this case. This provides an opportunity for determining the relation between distance and dosage in the inoculum potential complex.

It seems advisable to expand the original definition of inoculum potential as given by Horsfall (7, p. 5) and consider it as "the disease-producing power of the host environment," assuming, of course, that pathogens constitute a part of that environment. Other things being equal, inoculum potential is a function of the dosage of spores. It can be assumed that the dosage of spores normally decreases with distance from the source of inoculum, whether the spores are disseminated by beetles, wind, or some other vector. In spread of Dutch elm disease, therefore, if it is shown that response in percentage infection, as probits, decreases with the logarithm of the distance, then the inverse of distance can be substituted for dosage in the typical dose-response relation. Distance, therefore, could be considered to have an effect inversely equivalent to that of dosage of spores.

METHODS

To obtain pertinent information on the probability of infection by spread of the fungus from diseased elms, isolated, naturally infected trees were selected as centers for three plots in widely separated woodland and roadside areas in Fairfield County, Connecticut. Long distance dispersal of contaminated beetles by wind probably led to infection of these isolated trees. The experimental design for these plots included several requisites: (1) a single naturally diseased tree at the center of each plot, as a source of inoculum; (2) a distribution of healthy elms in the vicinity approaching randomness; (3) separation of the plots from other diseased elms by at least one-half mile; (4) consideration of primary infections only, so that spread from subsequently infected elms in the plot would not confuse the picture; (5) uniformly high level of *Scolytus* beetle infestation on diseased trees at plot centers; and (6) freedom of plots and immediate vicinity from beetle breeding wood.

When first observed in the summer of 1941, each of the naturally infected elms at the center of each plot was severely diseased, and *S. multistriatus* adults were emerging from them. Some emergence undoubtedly occurred also during 1940. By the spring of 1942, all three trees had died from the Dutch elm disease. The diameters (D.B.H.) of these original infected trees were: plot 1, 18 inches; plot 2, 38 inches; and plot 3, 24 inches. Beetles emerged from secondary infections in 1942, so that disease appearance after 1942 could not be attributed to spread from the original diseased trees.

During August and September, 1942, data were taken on subsequent infections resulting from spread of the fungus on these plots. All elms within approximately one-quarter mile of the diseased tree at each plot center were examined for foliar symptoms of disease, and all elms within a 320-foot radius of the original diseased tree were mapped and data were

taken on new infections. Trees suspected of being diseased were sampled and laboratory cultures were made by the usual technique.

RESULTS

The proportion of infected trees on the plots decreased with the distance from the source of inoculum, as might be expected (Fig. 1, Table 1). Inten-

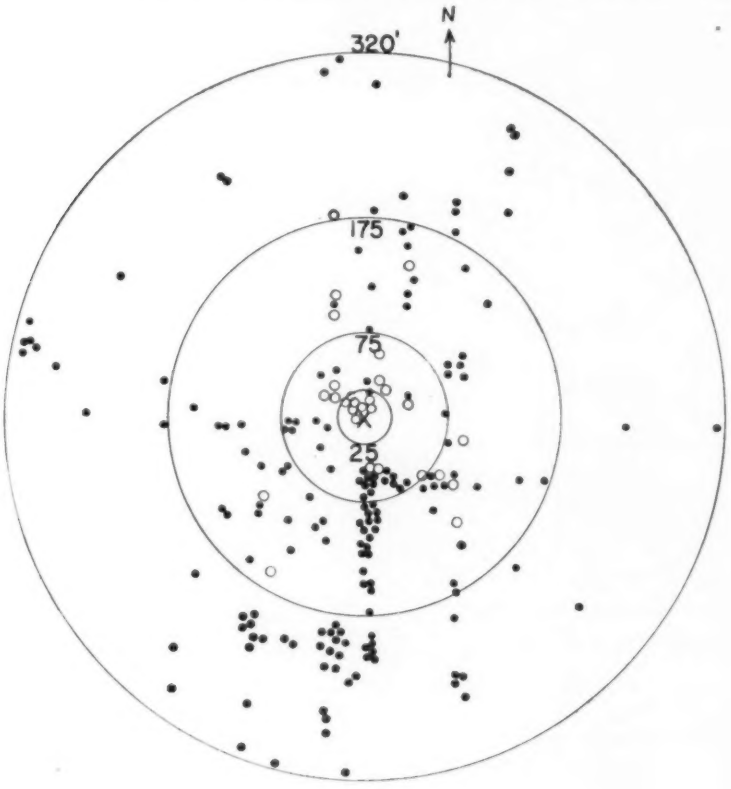

FIG. 1. Diagram showing spread of Dutch elm disease from infection center (X). The diagram combines data from three plots; on each of them, at "X," was an isolated, infected elm.

sification of the disease in the immediate vicinity of the original infections was very marked. Seventy-five per cent of the new infections appeared within 100 feet of the original diseased trees; 40 per cent of the trees within 75 feet of the plot centers became diseased. The maximum distance of spread was 180 feet.

Fourteen diseased elms resulted from the spread of *Ceratostomella ulmi* from the original diseased tree on plot 1 in Norwalk, 8 new infections ap-

TABLE 1.—*Spread of the Dutch elm disease from single trees, naturally infected, on isolated plots in Fairfield County, Connecticut*

Plot	Distance from original diseased elm	Mean distance of all elms within group	Total elms	Elms becoming diseased by 1942	
	Feet	*Feet*	*No.*	*No.*	*Per cent*
1. Norwalk	0.0– 25	13.3	5	4	80.0
	25.1– 75	44.0	12	7	58.3
	75.1–175	124.8	20	3	15.0
	175.1–320	254.0	19	0	0.0
2. New Canaan	0.0– 25	.....	0	.....	.....
	25.1– 75	57.6	17	2	11.8
	75.1–175	108.4	39	5	13.1
	175.1–320	242.8	21	1	4.5
3. Fairfield	0.0– 25	17.4	4	4	100.0
	25.1– 75	57.2	8	1	12.5
	75.1–175	127.2	18	1	5.6
	175.1–320	222.0	32	0	0.0
Totals for all 3 plots	0.0– 25	15.2	9	8	88.9
	25.1– 75	53.2	37	10	27.0
	75.1–175	117.2	77	9	11.7
	175.1–320	236.5	72	1	1.4
			195	28	14.4

peared on plot 2 in New Canaan, and 6 new infections on plot 3 in Fairfield.

The spread data were classified into the following distance groups: 0 to 25, 25.1 to 75, 75.1 to 175, and 175.1 to 320 feet from the plot center. When the mean distances (12.5, 50, 125, and 247.5 ft.) were plotted against the average percentage infection for all three plots on logarithmic probability paper, a linear relation was evident, indicating that the probability of infection decreased with the logarithm of the distance from the disease source.

TABLE 2.—*Summary of statistical analysis of data from Dutch elm disease spread plots*[a]

Variation	n	χ^2	P
Between means of plots	2	2.431	0.29
Between slopes of plots	2	5.401	0.067
About plot curves	5	3.664	0.59
Total	9	11.496	0.24

Combined slope b_c equals -2.504
Regression equation: $Y = 8.865 - 2.504X$

[a] A copy of the statistical data and calculations may be obtained on request.

The data were then analyzed statistically,[1] considering each plot separately. The mean distances of trees within each distance group were calculated, and the data corrected by the use of weighted probits (1). The slopes of the regression lines for each plot and for the three plots combined were calculated, and the significance of the variations between the slopes, between the position of the lines, and about the curves was found by applying a Chi-

[1] The writers are indebted to Dr. C. I. Bliss for assistance with statistical techniques.

square test (1). Significance of the comparisons of variations was judged at a probability level of 1 to 20 (P = .05).

The results of the analysis are shown in table 2. The differences between the positions of the curves (between means of plots) were not significant (P = .29), nor were the differences between the slopes, although the latter approached significance (P = .067). Variations about the plot curves were far from significant. A combined slope (b_c) and regression equation thus may be used to describe the results of the study.

The combined slope "b_c" was calculated by the usual formula and was found to equal -2.504. The regression equation $Y = \bar{y} + b_c(X - \bar{x})$ thus be-

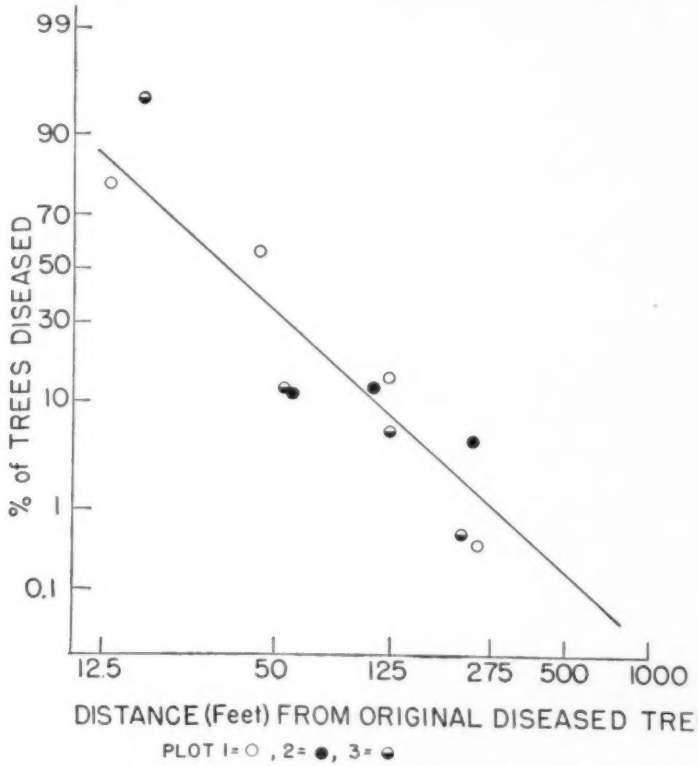

FIG. 2. Regression curve calculated from Dutch elm disease spread data, plotted on logarithmic probability scale. Points along the calculated line are observed infection percentages for the mean of each distance group on each of the three plots.

comes $Y = 8.865 - 2.504X$. The regression curve plotted from this equation is shown in figure 2, with the observed points for percentage infection on each plot at the mean distance for each grouping also shown.

From the regression line (Fig. 2) it is apparent that when all probabilities are combined the chances of infection for an elm within 25 feet of the original diseased tree were about 6 in 10. At 50 feet the chances were about 3.5 in 10; at 100 feet, 1 in 10; at 300 feet, 1 in 100. The accuracy of extrapolated values is particularly enhanced by the precision of the calculated

regression line, and it can be seen from the graph that the probabilities of infection at 500 feet were about 1 in 500, and at 1,000 feet they were approximately 1 in 10,000.

Inspection of the composite map (Fig. 1) revealed a considerably larger percentage of new infections in the north half of the plots than in the south half. Of 65 elms in the north half, 18 or 27.7 per cent became infected, as contrasted to 10 infections in 130 elms (7.7 per cent) in the south half. When the data were adjusted for the difference in initial population and were analyzed statistically by a Chi-square test, the difference between the percentage of infections in the north and south halves of the plots was highly significant (χ^2 between means equals 5.526, n = 1, P = .01). The slopes are practically parallel (χ^2 between slopes = .011, n = 1, P = .92).

Calculation of the relative level of infection (antilog M) (9) demonstrated that the spread of infection to the north was twice as great as to the south of the plot centers (antilog $M = 2.0 \pm .7$, $M \pm s_M = .301 \pm .15597$). For example, where the distance for 50 per cent infection on the north was 50 feet, that on the south was 25 feet. The χ^2 between means and the comparison of M with its error reveal that the difference between north and south is just significant according to statistical measures.

DISCUSSION

This evidence that the probability of infection in Dutch elm disease decreases linearly with the logarithm of the distance from the source of inoculum provides further data on the relation between dosage and response in biology. The premise that the distance from a source of inoculum might be considered to bear an inverse linear relation to dosage of spores is substantiated. Since the mechanism of penetration is via beetle feeding punctures, the number of punctures would be expected to decrease also as the distance increases logarithmically. When data presented by Wolfenbarger and Jones (10) are plotted on logarithmic probability paper this is the case. Essentially the main factor determining the response, however, is the effective spore dosage reaching the tree, regardless of the vector.

If distance acts similarly to dosage, this relation should appear in other work. Re-calculation of data presented by McCallan (8) shows that the percentage germination (as probits) of *Sclerotinia americana* conidia at varying distances from a drop of Bordeaux mixture on a glass slide increased with the logarithm of the distance. Also, when data of Bonde and Schultz (2) were plotted on logarithmic probability paper, the percentage (as probits) of potato late blight in a field decreased with the logarithm of the distance from infected refuse piles. Hence the same laws are operating whether the distance factor is concerned with the amount of Dutch elm disease, beetle feeding punctures on elm, the effectiveness of Bordeaux mixture, or spread of potato late blight. Distance in all of these cases follows the same dose-response principle as do dosages of spores in producing disease, or of fungicides in preventing disease.

Frampton, Linn, and Hansing (5) presented data on the spread of the yellow-dwarf virus into potato fields and of the aster-yellows virus into endive beds. Data from some of these fields, when replotted on logarithmic probability paper, follow the log-probit dose response relation. Data from other fields do not follow this relation, however; the types of curves obtained with these indicate that complicating factors such as multiple sources of inoculum may be affecting the spread pattern.

These data also furnish information of significance in control of a specific disease. Elm owners wish to know the probabilities for infection in a group of elms at a given distance from a source of inoculum such as a diseased tree or a pile of infested wood. Control officials are concerned from the point of view of the distance (width of local control zone) required for a low level of infection. The elm owner is interested in the probabilities of infection at a given distance. The control official wishes to know the distance for any given probability of infection. Either can be obtained by interpolation on a regression line, as in figure 2. Both are determined by two characteristics of the regression line: position and slope.

The position of the line should be governed by: (1) the amount of fungus inoculum present, (2) number of beetles, (3) number of elm trees and the randomness of their distribution. With an increase in the amount of fungus or number of beetles, or a decrease in the number of elms, the regression curve should shift to the right.[2] Under these conditions the width of the protective zone should be widened and the probability of infection at any given point would increase. Under opposite conditions the regression line should shift to the left and the probability of infection at any distance would decrease.

The slope of the regression line will presumably be altered by various site, topographical, and weather factors, and by extraneous factors such as the presence of devitalized or dying elm wood which would attract beetles for breeding sufficiently to change expected infection percentages. If the elm distribution does not approach randomness, these generalizations will undoubtedly be confused.

Local spread is not restricted to the relatively short distances found here by limitation in flight or dispersal of the vector. The distance of occasional, chance dispersals of *Scolytus multistriatus* is known to be more than two miles and may in some instances extend to greater distances.

Wind is apparently a factor in the long distance dispersal of *S. multistriatus* adults (4), and hence in the spread of Dutch elm disease. The current data indicate that wind also influences local spread. The difference between the relative amount of infection in the north and south halves of the combined plots was significant; wind was probably the main factor responsible for this difference. The prevailing winds are from the south in the plot localities during months of beetle emergence. These results

[2] Data of Wolfenbarger and Jones (10) tend to confirm this. Plotting their data on logarithmic probability paper showed displacement of the regression line to the right when five times as many beetles were present, but the slope of the line was not affected.

demonstrate the importance of exposure and topography in determining the width of local control zones.

The data for these three plots and a discussion of the factors which affect local spread of Dutch elm disease provide useful information for estimating protective barrier zones in local control. It should be recognized that considerable variation in probabilities of infection can be expected with varying local conditions and that these calculated probabilities apply only to the average conditions on these 3 plots.

SUMMARY

Statistical analysis of data from 3 plots to study spread of the Dutch elm disease from large, naturally infected elms showed that the probability that a tree will become infected decreased directly with the logarithm of the distance from the disease source. The spread of this pathogenic fungus (*Ceratostomella ulmi*) therefore is in agreement with the dose-response relation that occurs in many fields of science. Since a rectilinear relation exists between the logarithm of the distance and the percentage infection (as probits), distance from a source of inoculum has an effect inversely equivalent to that of dosage of spores.

By calculating regression equations for each plot and comparing the variations by a Chi-square test, the data were found homogeneous; the 3 equations could be combined to give one regression line to describe the observations. This calculated line is useful in determining probabilities of infection of trees at varying distances from the disease source, and thus has significance in local control measures.

Intensification of disease was very marked in the immediate vicinity of the original infected elms. Seventy-five per cent of the new infections on the 3 plots were within 100 feet of the original diseased trees; 40 per cent of the elms within 75 feet of the disease source became infected.

The distance of dissemination of the fungus to the north of the plot centers was approximately twice that to the south; the distance for 50 per cent infection on the north was 50 feet, on the south, 25 feet. Statistically, the difference in amount of infection for the two halves was at the margin of significance. Prevailing south winds during beetle emergence apparently caused this divergence.

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STANDARD AND NEW FUNGICIDES FOR THE CONTROL OF COVERED KERNEL SMUT OF SORGHUM AND THEIR EFFECT ON STAND[1]

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(Accepted for publication June 15, 1944)

The sorghum grower in the Southern Plains area of the United States is constantly confronted with the problem of obtaining satisfactory stands of plants free from covered kernel smut. Experiments at the Kansas Agricultural Experiment Station (1, 4) were the first to demonstrate that chemical dust treatments were more satisfactory than wet treatments for the control of covered kernel smut. Treatment of sorghum seed soon became an adopted farm practice on a large acreage in Kansas and other sorghum-producing areas. Copper carbonate and New Improved Ceresan, the fungicides most often recommended, have satisfactorily controlled smut and are of value in promoting good stands, but they have some limitations.

When unsatisfactory environmental conditions prevail between the date of planting untreated sorghum seed and emergence of seedlings, the percentage stand of plants is reduced considerably. Fearing poor stands, the grower generally sows more sorghum seed than is desirable. This may give a good stand under unfavorable environmental conditions; on the other hand, when environmental conditions are favorable, too heavy a stand is obtained, which is detrimental under conditions of average or below average precipitation. Fungicides that will stabilize the stand when a recommended rate of seed is planted are desirable, especially when they also control smut. The use of such fungicides would enable the grower to conserve seed and to determine more accurately the rate of seeding based on laboratory seed germination tests.

An experiment was designed to learn what chemical dusts achieve satisfactory control of covered kernel smut, promote better stands than the dust fungicides commonly used, and improve the vigor of the seedlings, especially when in cool, moist soils. Corona Coppercarb and New Improved Ceresan (5), with the new fungicides Arasan, Spergon, and DuBay 1452–C, micronized free-flowing sulphur, and micronized wettable sulphur were used. The sulphur dusts were of immediate importance because of the wartime critical shortage of copper.

Pink kafir sorghum seed, with a laboratory germination of 93 per cent, was inoculated with covered kernel smut at the rate of 1 gram of spores to 200 grams of seed. On April 20, 1943, separate portions were treated with the inorganic fungicides, micronized free-flowing sulphur, micronized wettable sulphur, and Corona Coppercarb, each at the rate of 3 oz. of the chemical dust per bushel of seed. Similar portions of seed were treated with

[1] Contribution No. 457 from the Department of Botany, Kansas Agricultural Experiment Station.

the "nonvolatile" organic fungicides Arasan and Spergon at 2 and 3 oz. per bushel, respectively, and with the volatile organic fungicides New Improved Ceresan and DuBay 1452–C (7.7 per cent ethyl mercury-p-toluene sulfonanilide), each at ½ oz. per bushel.

Two days later four 20-gram lots of seed from the untreated sack and from each of the treated sacks were planted in the field in randomized 75-foot rows. Each treatment was replicated four times. The seed was planted at an earlier date than sorghum seed is usually planted at Manhattan to increase the probability of there being environmental conditions unfavorable for seed germination between planting and emergence of the seedlings. This earlier date of planting would generally give greater comparative differences in stand of plants between treatments than would later

TABLE 1.—*Effect of seed treatment on the stand of sorghum plants and on the control of covered kernel smut.*[a] *Manhattan, Kansas, 1943*

Seed treatment	Rate per bu.	Av. emergence of plants		Final stand of plants		
				Mature	Smutted	
	Oz.	*No.*	*Per cent*	*No.*	*No.*	*Per cent*[b]
No treatment	....	360	34	457	251	56.8
Micronized free-flowing sulphur	3	366	34	451	4	0.9
Micronized wettable sulphur	3	367	35	458	7	1.3
Corona Coppercarb	3	609	57	569	24	4.2
Arasan	2	713	67	560	2	0.4
Spergon	3	749	71	561	2	0.4
New Improved Ceresan	½	657	62	556	0	0.0
DuBay 1452–C[c]	½	648	61	533	0	0.0
Difference necessary for significance:						
5 per cent level	....	85	....	.....	.....	5.0
1 per cent level	....	116	....	.....	.....	6.8
0.1 per cent level	....	156	....	.....	.....	9.2

[a] Seed treated April 20 and planted April 22; emergence notes taken May 26 to 27; plants thinned May 28 to 29; smut notes taken September 1.

[b] Average of percentages.

[c] 7.7 per cent ethyl mercury-p-toluene sulfonanilide.

plantings. Stand counts were taken five weeks later when the plants were several inches tall. The data were analyzed statistically by analysis of variance.

There was no significant difference in stand of plants from seed which was untreated (34 per cent) and that which was treated with either of the sulphur fungicides (34 per cent and 35 per cent) (Table 1). There was no apparent beneficial or detrimental effect due to the sulphur seed treatments. This substantiates the earlier work of the writers and other investigators (1, 2, 3, 4, 6) in which similar stands of plants were obtained from untreated seed and seed treated with sulphur.

The stand of plants for Corona Coppercarb was 57 per cent; for Arasan, 67 per cent; for Spergon, 71 per cent; for New Improved Ceresan, 62 per cent; and for DuBay 1452–C, 61 per cent (Table 1). The increase in stand

from seed treated with either Corona Coppercarb or any of the organic fungicides over untreated seed was highly significant. In this experiment the stands of plants for the treatments Spergon and Arasan were the highest, each being significantly higher than that for Corona Coppercarb, and together being significantly higher than for New Improved Ceresan and DuBay 1452–C. Recently better stands from seed treated with Spergon and Thiosan (Arasan) than from seed treated with New Improved Ceresan have been obtained elsewhere (2). DuBay 1452–C was about equal to New Improved Ceresan in increasing the stand of sorghum plants in the experiments at Manhattan (Table 1).

After the stand counts were taken the plants were thinned to approximately 7-inch intervals. When the plants headed, notes were taken on the total stand and on the number of smutted plants. Percentages were calculated and the data were analyzed statistically by analysis of variance. The smutted plants for the untreated checks averaged 56.8 per cent, for Corona Coppercarb 4.2 per cent, and for the other treatments from none to 1.3 per cent (Table 1). The difference between the percentages of smutted plants for the untreated check as compared with any of the fungicide treatments was highly significant. There was no significant difference in the percentage of smutted plants for any of the fungicide treatments.

Summing up the results of this experiment, the fungicides Spergon, Arasan, New Improved Ceresan, DuBay 1452–C, and Corona Coppercarb were satisfactory in increasing the stand of sorghum plants. The two sulphur fungicides had neither an apparent beneficial nor a detrimental effect on the stand of sorghum. All of the fungicides used effectively controlled covered kernel smut. Thus, several efficient, economical, and practical seed disinfectants are available other than those in which copper and mercury are the active ingredients. This matter is important because of war conditions.

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STRAINS OF PRUNE DWARF[1]

R. S. WILLISON

(Accepted for publication June 24, 1944)

In recent years prune dwarf, attributable to Prunus virus 6 (13) or *Nanus pruni* H. (10), has been observed at widely separated points in the United States and Canada (9). First discovered in New York State in 1930 and reported in 1936 by Thomas and Hildebrand (14), it has since been observed in the Niagara Peninsula of Ontario in 1937 (1) and in the Penticton district of British Columbia in 1938 (12). Hitherto prune dwarf has been found in a recognizable form in nature, only on Italian prune (12, 14), and on Italian prune topworked on Damson (1, 8). Hildebrand (8) not only has demonstrated that Damson could carry the virus without showing symptoms but also has transmitted prune dwarf by budding to several prune type plums, to Lombard plum, and to peach, but not to cherry. The present article, by comparing symptom expression on a series of common hosts, submits evidence that two viruses from naturally infected sweet cherry and two from plum or prune are in reality four strains of prune dwarf virus.

SOURCES

The disease was first discovered in Ontario in an orchard near Grimsby, where Damson had been topworked to prune. Preliminary indexing on peach seedlings gave some not very convincing signs of transmission. Strain 1 was obtained in 1939 from Italian prune, originally from the same orchard, that had been grafted on Damson in a neighboring orchard. Grand Duke plums on Damson in this orchard were apparently healthy.

Strain 2 came from the Beamsville district in 1939, from an unknown variety of blue plum with striking symptoms of prune dwarf after being topworked on Damson. Italian prune on Damson at the same location was also typically affected in some instances but not in others, indicating that some of the Damsons were healthy.

The two viruses procured from sweet cherry are designated, for convenience, as strains 3 and 4 of prune dwarf, but for the time being they should be regarded as causing separate diseases. Strain 3, which causes Elkhorn ring spot (9), was found in a garden near St. Catharines in 1940 on a tree of the Elkhorn variety, some leaves of which were marked with small ring spots often with necrotic centers, and with larger rings and blotches (Fig. 3, J), while the fruit had small sunken areas and internal brown spots. The leaf symptoms in the illustration are somewhat exaggerated, being photographed with transmitted light. The tree was symptomless in 1941, but, as there was no way of knowing how long it had had the disease, it was impossible to decide whether the striking symptoms of 1940 were due to the cool,

[1] Contribution No. 777 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

wet season or to the initial shock of infection. Both the shock effect and the influence of temperature on symptom expression have been noticed in connection with other viroses on Prunus hosts (1, 5, 6, 11).

Strain 4, responsible for Eagle mottle (9), was picked up in 1940 near Niagara Falls on sweet cherry, variety Black Eagle. The owner's cause of complaint was the tree's unfruitfulness for several seasons. The only other symptom observable in June, 1940, was an inconspicuous foliage mottle.

A fifth strain was obtained from Damson trees in an orchard near Winona in 1940 but has not been used in these experiments because preliminary trials indicated close relationship with strain 1.

EXPERIMENTAL HOST RANGE

In the experiment, 14 host varieties, together with seedlings, were used, namely: *Prunus domestica* var. Italian prune, German prune, Lombard, Reine Claude, and Grand Duke; *P. salicina* var. Abundance; *P. persica* var. Elberta, Rochester, and seedlings; *P. cerasus* var. Montmorency; *P. avium* var. Napoleon, Black Tartarian, Black Eagle, and Elkhorn; *P. armeniaca* var. Niagara; *P. cerasifera*, Myrobalan seedlings; and *P. mahaleb*, seedlings.

METHODS

The complete series of inoculations was essentially the same for each of the four strains and was developed over a period of three years as illustrated in figure 1. In 1940 and 1941, triplicate series of seedling peaches of the current year's growth were double-budded, first with a bud carrying the virus strain under investigation and then with a bud of the desired "healthy" variety. In 1942, direct inoculation on 2-year nursery stock, in duplicate, was employed for some varieties and double-budding, in triplicate, for others (Fig. 1). Throughout the double-budding experiments, each of the "healthy" varieties was of clonal origin indexed as required. The results of indexing are not shown in the chart (Fig. 1) but the clons were healthy except as noted. The nursery stock varieties were obtained direct from a local nursery and were thus of unknown history and without definite proof of health. Because of the possibility of the occurrence of masked viroses in certain stone fruits, the use of unindexed nursery stock is not entirely satisfactory and the lack of the necessary seedlings unfortunately made it impossible to index the 196 individuals in the plantation. However, no indications of virus disease were apparent in the nursery stock during the summer of 1942. The plums and peaches in this block showed no signs of prune dwarf in 1943 except where inoculated with one or other of the four strains and so could be assumed to have been healthy so far as that disease was concerned. Half the cherries, both in the four prune-dwarf series and in series inoculated with other viruses, were indexed in 1943 on peach and Italian prune (Fig. 1) to verify transmission and to test the purity of the transfer.

The double-budding technique was in some respects better than the inoculation of larger trees because, besides facilitating indexing and the use of

clonal stock, it tended to give an earlier expression of symptoms. There was, however, some difficulty in getting one or two of the plum varieties to grow on peach stock, while the cherries failed to grow on peach and were somewhat

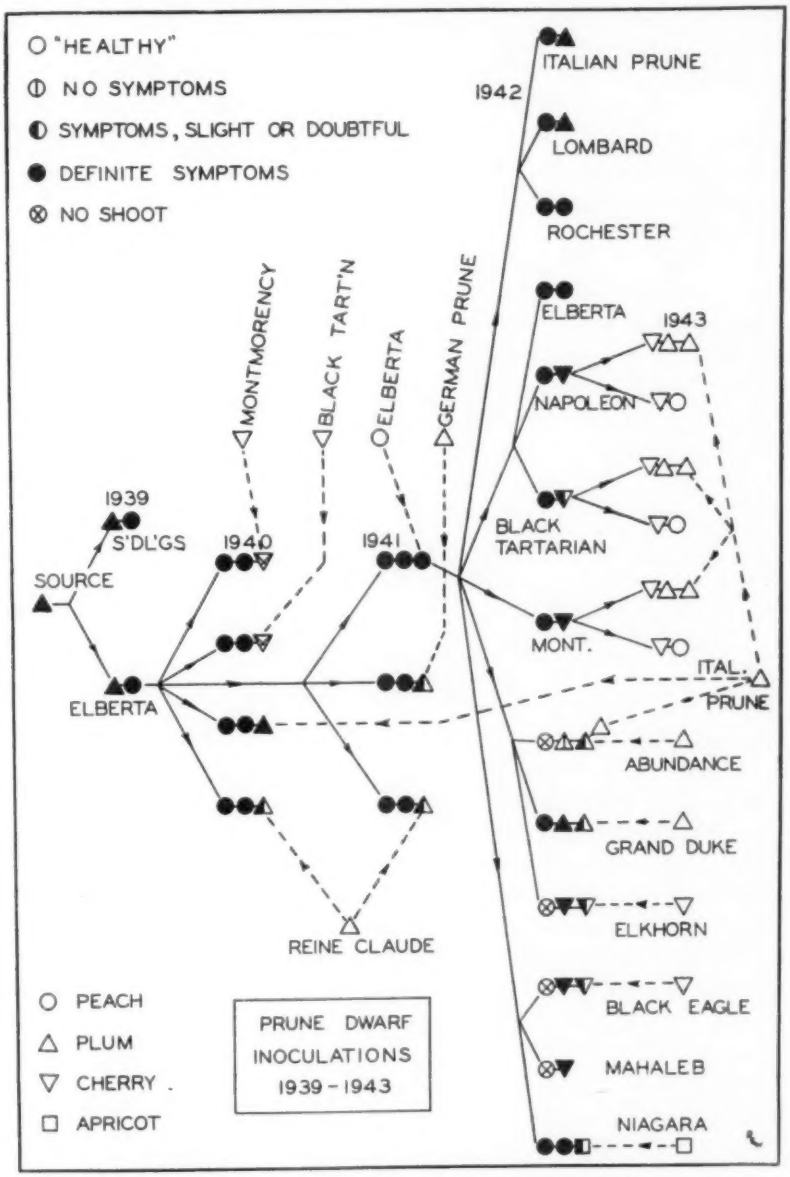

FIG. 1. Typical inoculation scheme tracing the transmission of a strain of prune dwarf from the original source through sub-inoculations and showing the varieties tested and the development of clons in "the double-budding" experiments. All sets of inoculations in triplicate except on nursery stock in 1942 which were in duplicate.

uncertain even on Mahaleb. The failure of inserted diseased buds to produce shoots did not prevent transmission of the virus, even where the whole

TABLE 1.—*Synopsis of symptom expression*[a] *of prune dwarf virus strains on various stone fruit varieties*

Host	Strain 1	Strain 2	Strain 3	Strain 4
Italian prune	A, B, C, D ±	A, B +, C +, D ±	A, B, C, D ±	A, B, C, D ±
German prune	D −/=, R	D −	D −/=, R	D −/=, R
Lombard plum	A ?, B, C, D −	A ?, B, C +, D, E +	A ?, B, C, D −	A ?, B, C, D −
Reine Claude plum	A −, C −, R	A, C, D	O	A −, C −, R
Grand Duke plum	D −/=	D		
Abundance plum	D ?/=	D −	D ? /=	D ? =
Elberta peach	A −, C, D =, E, R ±	A, C +, D, E, F ±	A −, C −, D −/=, E −, F ±, R ±	A −, C +, D =, E, F ±
Rochester peach	A −, C, D =, E, R ±	A, C +, D, E	A ?, C −, D −/=, E −, F ±, R ±	A −, C +, D =, E, F ±
Seedling peach	A −, C, D =, E, F ±, R ±	A, C +, D, E, F ±	A ±, C −, D −/=, E −, F ±, R ±	A −, C +, D =, E, F ±
Montmorency cherry	D −	C ?, D	D − /=	A −, D
Napoleon cherry	D −	C −, D	A ?, C −, D −/±	C −, D
Bl. Tart 'n cherry	D −/±	D −	O	D
Black Eagle cherry	D ?	D −	D ?	D ?
Elkhorn cherry	O ?	D ?	D ?	
Niagara apricot	A, C −	A, C, D ± ?	A −, C ±, D ?	A −, C
Myrobalan sdlgs.	O ?	C ±, D ±	O ?	O ?
Mahaleb sdlgs.	D ±	D	D ±	D ±

[a] Key:— O: No symptoms; A: Delayed foliation;
B: Strapping and rugosity of leaves (characteristic on prune);
C: Dwarfing (reduction in number and length of internodes);
D: Markings on leaves; E: Wavy leaf margins;
F: Superficial bark necrosis; R: Recovery.
=: Transient; −: faint or slight; +: pronounced or severe; ?: doubtful; ± may or may not occur.

graft-piece died during the winter. As all budding was done in August or early September, the phrase "the first season" refers not to the year of budding but to the next following.

SYMPTOMATOLOGY

The effects of the four strains on the various hosts of the range are compared in synoptic form in table 1.

On Italian prune.—All four strains produced the characteristic symptoms of prune dwarf. One of the earliest indications of transmission was a delay in the opening of buds. Leaves, as they developed, became strap-like, narrow, somewhat thickened, and sometimes emarginate, with roughened or pebbled surfaces and frequently a fine mosaic mottle (Fig. 2, A). Affected leaves and shoots were smaller than normal. Symptoms appeared in the first season in the double-budding experiments but not on the nursery stock except when the inoculated branch was cut back and then only near the point of inoculation. Some differences in severity of reaction were noted, strains 2 and 4 being more severe than strains 1 and 3. For example, prune buds in the 1940 experiment with strain 2 put out in the spring of 1941 severely affected and dwarfed shoots which died during the summer. Prune shoots inoculated at the same time with strain 3 have survived for at least three seasons though showing quite striking symptoms annually. The symptoms of the two cherry strains, 3 and 4, on Italian prune are shown in figure 2, E and G.

On German prune.—With strains 1, 3, and 4, some transient mild mottle, followed by whitish or chlorotic areas on some leaves, was observed in the first season. No symptoms were evident in the second season. With strain 2, however, the mottle was accompanied by a slight distortion and blistering of early leaves, while faint patterns mostly of the oak-leaf type appeared in June (Fig. 3, K). The latter symptoms occurred again in the second season.

On Lombard plum.—On nursery stock, all strains caused slight chlorotic flecking and spotting early in the season and dwarfing of shoots, localized near the inserted diseased buds. Where the inoculated branch was cut back to the bud, the dwarf shoots bore leaves very much like those of affected Italian prune (Fig. 2, D). Strain 2 was more nearly systemic in its effects and in addition to the localized symptoms caused a variety of chlorotic patterns such as lines, rings (Fig. 2, C) and marginal V-shaped blotches, and some necrotic spotting, while many leaves were distorted by twisting, asymmetry, and pronounced waviness of the laminae, frequently associated with the chlorotic areas (Fig. 2, B). Some shortening of internodes tended to give the new growth a semi-rosetted bunchy appearance in the late summer.

On Reine Claude plum.—In the 1940 and 1941 experiments with strains 1 and 4, Reine Claude showed no symptoms beyond a slight delay in foliation and slight dwarfing in the first season only. Strain 3 had no apparent effect. With strain 2, however, growth has been stunted and oak-leaf and coarse line patterns of varying intensity have appeared in June and July for at least three seasons.

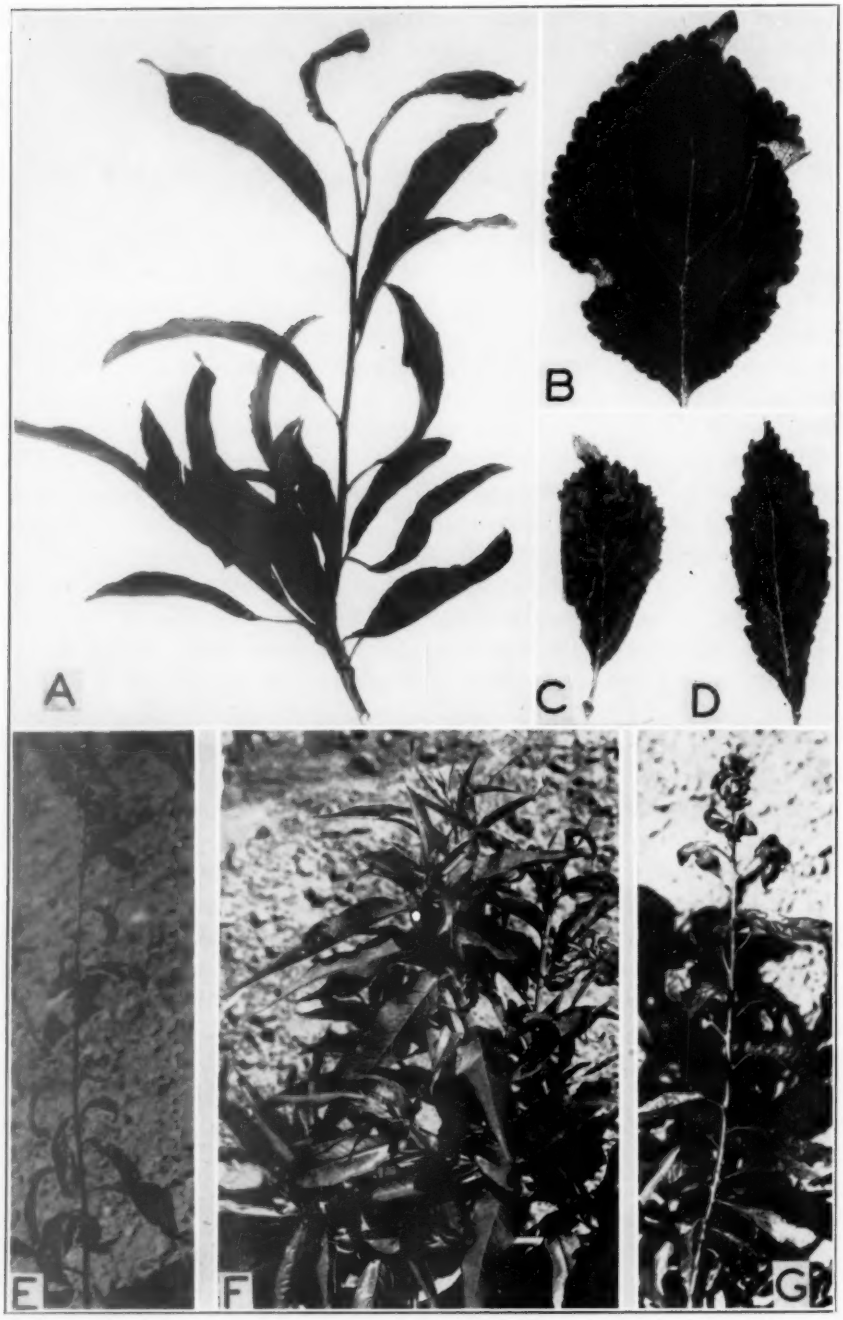

FIG. 2. A: Typical symptoms of strain 1 on Italian prune; B, C: strain 2 on Lombard showing wavy margins (B) and marking and narrowing of leaves (C); D: strain 4 in Lombard; E: strain 3 on Italian prune; F: strain 1 on peach seedling; G: strain 4 on Italian prune.

On Grand Duke plum.—Only strains 1 and 2 were used for inoculating Grand Duke in 1942. This variety was little affected by 1, traces of mottle and ring spotting appearing on the first few leaves. Strain 2, though having little or no effect on vigor, produced quite striking line patterns and some oak-leaf which persisted throughout the summer (Fig. 3, L).

On Abundance plum.—Although a few, faint, transient, pale green rings appeared on the first few leaves of one Abundance shoot inoculated with strain 1 and faint chlorotic areas on other plants inoculated with strains 1, 3, and 4, these symptoms were too illusive to be diagnostic. Evidence of transmission of strain 2 was only slightly more satisfactory, as traces of oak-leaf and other patterns were observed on the younger leaves in July. In 1943, therefore, healthy Italian prune buds were grafted in the Abundance to test for the presence of prune dwarf. Results of this budding of course will not be available until the growing season of 1944.

This clon of Abundance, though itself quite healthy in appearance, when indexed on peach, gave some indications that it carried a virus of the peach-yellows-little-peach group.

On peaches.—Though the differences between the strains of prune dwarf tended to be more apparent on peaches than in some other hosts, there has been little variation in the reaction of the different peach varieties to any one strain of the virus. Minor differences in the degree of symptom expression have been encountered among seedlings, but, for present purposes, a description of the effects of each prune dwarf strain can be applied to peaches generally.

Strain 1 characteristically, especially in the first season, produced a slight delay in foliation and a moderate dwarfing by reducing both number and length of internodes (Fig. 2, F). Some early leaves showed faint marking, such as mottles, chlorotic spots, feathery patterns, and confluent rings, which disappeared later in the season. The newer leaves were often loosely rolled upward and inward from the margins and were more or less stiff and upward-pointing or had wavy margins (Fig. 2, F). Superficial bark necrosis sometimes occurred near the point of inoculation. Trees affected with strain 1 tended to recover after the first season.

The symptoms with strain 2 were of the same nature but were always more severe, while the leaf markings, usually a fine network of small rings and fine lines, persisted throughout the summer. The original inoculation to Elberta resulted in a very pronounced shortening of internodes amounting almost to a loose rosette. The leaves were narrower, smaller, and stiffer than normal, the bark became roughened, and the condition of the tree deteriorated from year to year. In sub-inoculations from this tree, reactions were somewhat milder and there was slight recovery in the second and third seasons, suggesting that the strain had lost some of its aggressiveness after passage through peach.

Strain 3, on the other hand, was generally less dwarfing than 1 though resembling that strain in other respects. On some seedlings, the symptoms of 3 were almost suppressed.

The original inoculations with strain 4 on seedlings induced a dwarfing almost as severe as that caused by strain 2, but with sub-inoculation strain 4 became intermediate between strains 1 and 2 in its dwarfing effect. Leaf markings like those described for strain 1 appeared only on early leaves, but strain 4 frequently imparted a yellow cast to the foliage by exaggerating the "growth mottle" sometimes seen on the leaves of healthy peach trees. Normally the "growth mottle" consists of pallid interveinal tissues outlined by dark green veins and is usually outgrown as the leaf matures. On the trees affected by strain 4, the pallor was heightened to a fairly vivid and persistent yellow.

On Montmorency cherry.—As all cherries in the double-budding experiments of 1940 and 1941 failed to grow, only one season's observations, on the 1942 series, have been available for any of the cherry varieties. The only symptoms of strain 1 on Montmorency were some pale green rings and mottle and traces of fine brownish lines on the early formed leaves. Later leaves were symptomless.

With strain 2, there was a considerable amount of pronounced mottle, ringing, and chlorotic or necrotic spotting on some early leaves (Fig. 3, D) and on others a network of fine brown rings, lines (Fig. 3, E), and flecks (Fig. 3, F) which sometimes became necrotic. In July, line patterns were seen on some leaves but they had disappeared a month later. Strain 2 also appeared to have a slight dwarfing effect.

Strain 3 caused only a faint, coarse mottle early in the season. Even these symptoms were rather indefinite and transient.

Strain 4 gave rise to slight delay in foliation and to considerable coarse mottle and ringing and to some necrotic spotting and flecking on early leaves only. In its reaction on Montmorency, 4 was thus intermediate between strains 1 and 2.

On Napoleon cherry.—All four strains induced various combinations and intensities of large ring and oak-leaf patterns on some leaves in early spring (Fig. 3, C). They were faint with strain 3, somewhat plainer with 1, and fairly well marked with 2 and 4, and more or less transient with all. In the case of strains 2 and 4, oak-leaf patterns appeared on a few new leaves as late as the beginning of July. All strains except strain 1 may have caused a slight stunting but it was impossible to be sure of this point. The buds in the vicinity of strain 3 inoculations were somewhat slow in opening.

On Black Tartarian cherry.—Symptoms on Black Tartarian were, if anything, less conspicuous than on Napoleon. Strain 3 was almost completely masked, while the markings of strain 1, if present at all, were faint on early leaves. With strain 2 the coarse-ring, line, and oak-leaf patterns were few and mild though apparent on new leaves until July (Fig. 3, A). Strain 4 symptoms were much the same as, though somewhat plainer than, those of 2 and persisted on the older leaves for some time (Fig. 3, B).

On Black Eagle cherry.—Black Eagle, inoculated with strains 1, 3, or 4 exhibited a faint mottle early in the spring, and with strain 2 some rings and coarse lines, but when indexed on peach and Mahaleb seedlings was itself

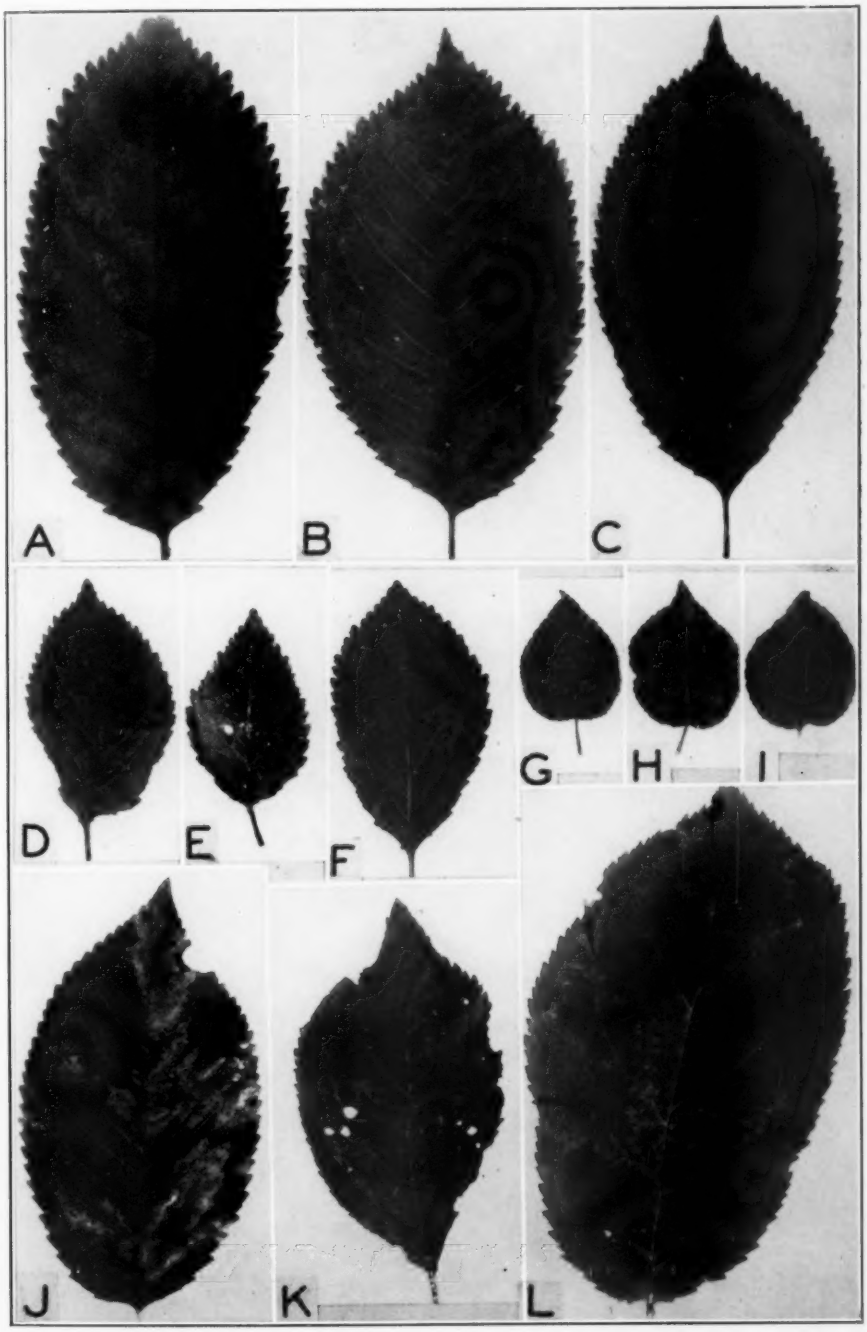

FIG. 3. A: strain 2 and (B) strain 4 on Black Tartarian; C: strain 4 on Napoleon; D–F: strain 2 in Montmorency, D: mottle and rings, E: brown lines and rings, F: brown flecking; G–I: typical symptoms on Mahaleb, G: lines and small rings, H: coarse rings, I: vein-banding; J: symptoms on Elkhorn source of strain 3; K: strain 2 on German prune; L: strain 2 on Grand Duke.

shown to be already virus-infected. The leaf markings on Eagle shoots, however, were in all probability induced by the prune dwarf virus as they were of the same order as those on the other sweet cherry varieties and appeared only on inoculated shoots.

The peach seedlings used for indexing this Black Eagle clon showed both fine and coarse rings and oak-leaf patterns, but the most striking symptom appeared in June as a necrotic streak down one side of each main shoot, near the tip, which was bent over to form a crook. Later the whole tip died. Indexed Mahaleb seedlings were somewhat dwarfed and their leaves were marked with faint oak-leaf and coarse ring patterns in mid-season. The identity of this virus is yet to be established, but it has none of the usual earmarks of prune dwarf.

On Elkhorn cherry.—This variety had either no symptoms or a faint mottle on early leaves. Unfortunately, indexing demonstrated that this supposedly healthy Elkhorn was already carrying a virus presumed to be prune dwarf virus on the basis of the symptoms on indexed peach. If this diagnosis is correct, the virtual absence of symptoms in the inoculated Elkhorn series is understandable since the tree, from which the buds were taken, had been selected as healthy and therefore either had always been symptomless or had long recovered from the initial shock.

On Niagara apricot.—There were no characteristic leaf symptoms of diagnostic value on apricot although, on some of the shoots inoculated with strain 2 or strain 3, some leaves had faint mottling or chlorotic spotting or streaking in the early part of the season. All strains and more especially 1 and 2 induced delay in foliation. Reduction in vigor and growth was considerable with strains 2 and 4 and somewhat less with 1 and 3. As a matter of interest and possibly of significance, two of the three apricot shoots inoculated with strain 2 died during the summer. The fact that, barring two buds that failed to take in other series, these were the only cases of mortality in the apricot experiment suggests that the more virulent strain 2 was responsible. A similar lethal effect with strain 2 has already been mentioned in connection with the double-budding experiment with Italian prune.

On Myrobalan plum.—Myrobalan seedlings exhibited no definite symptoms except with strain 2 when chlorotic mottles, lines, and rings appeared occasionally on early leaves and some plants were more or less stunted. Prune dwarf virus, however, can be transmitted through Myrobalan.

On Mahaleb cherry.—Mahaleb seedlings were quite variable in their reaction. Some were almost symptomless and some had early leaves marked with mottles, lines (Fig. 3, G), coarse rings (Fig. 3, H), and occasionally vein-banding (Fig. 3, I). With strain 2 and to a lesser extent with strains 1 and 3, coarse rings and oak-leaf patterns also appeared on leaves developed late in the summer.

DISCUSSION

In view of the striking similarity of the symptoms of these four viroses on each of the hosts which manifest them, and particularly on Italian prune,

Lombard plum, and peach, little argument is necessary to justify the thesis already proposed that all four are caused by strains of one virus. As a matter of fact, if any distinctions are to be made, there are greater differences between the two strains from plum than between the plum and the cherry strains. Prune dwarf, whether the causal strains of virus be considered individually or collectively, is manifested by symptoms of one or more of the following categories: (a) stunting or reduction of vigor; (b) leaf distortion; (c) patterns on leaves; and (d) crop reduction. The present experiments are not yet of sufficient duration to provide many yield data, but Hildebrand (8, 14) has presented some evidence on that point. With regard to the other types of symptoms, however, the combination exhibited has been much more specific to the host than to the strain.

It should also be observed that, on virtually every host in the range of these experiments, the strains if arranged according to increasing severity of effect would fall in the same order, namely: 3, 1, 4, and 2. Consequently differences occurring between strains, for example, the pattern-forming capacity so pronounced in 2, may be ascribed to differences in virulence. The markings on some hosts, especially with strain 2, bear some resemblance to those induced by the virus of line pattern (1, 3), but some transmission experiments with Shiro plum, which is one of the best indicators of line pattern (1, 9) and with line pattern on the host range, failed to show that that virosis is related to prune dwarf though its virus may be involved as a contaminant in strain 2.

Each species of *Prunus* and, in some instances, each variety has its characteristic reaction to prune dwarf. The typical response of peaches is some degree of dwarfing usually by internode shortening, mild leaf distortion in the form of wavy margins, and foliage patterns of varying intensities and persistence. In cherries, leaf patterns are almost exclusively predominant, at least as primary symptoms, and there is good evidence that some varieties of sweet cherries can become symptomless, or nearly so, with the possible exception of crop reduction. For that matter, *P. mahaleb* and, to a lesser degree, both sweet and sour cherries are not satisfactory differential hosts for prune dwarf because they respond to a number of distinct viroses with confusingly similar markings. Plums have so wide a range of reaction that they can be divided into at least three groups: (a) severely affected varieties, such as Italian prune and Lombard, in which leaf distortion and stunting of growth are the most striking symptoms; (b) moderately or slightly affected varieties, such as Reine Claude, German prune, and Grand Duke, which show almost no leaf distortion and little stunting but some leaf marking; and (c) varieties, such as Abundance and Damson, in which symptoms rarely occur.

The fact that some symptoms, especially leaf patterns, tend to occur only early in the season suggests that the degree of symptom expression may be affected by temperature or other conditions during the period of leaf formation. On the other hand, recovery in the second season would indicate

that, with some hosts at least, infection has an initial shock effect which is not sustained. Both factors are probably operative, though it is not yet possible to assess their relative significance.

The findings recorded here with respect to the effect of prune dwarf on German prune do not agree with those of Hildebrand (8). This discrepancy may have arisen because of differences in the strains of virus employed, but both Hildebrand's failure to obtain symptoms on cherries (8) and his description of peach symptoms would suggest that he was working with a comparatively mild strain and the mild strains in Ontario had little effect on German prune. So it would appear either that different strains of that variety were used in the two investigations or that there was some confusion regarding the identity of German prune in New York State and in Ontario. If either is true and because the same sort of situation might easily arise with other host varieties, stone fruit virus investigations would benefit from some form of standardization of experimental varietal material.

The similarity of the symptoms of prune dwarf on peach to those of rosette mosaic (2, 4, 7) has prompted Hildebrand (7, 8) to suggest a possible relationship between the two viruses. While conclusive proof is yet to be established, it is interesting to note another point of resemblance in that Cation (4) reported transmission of a disease which he diagnosed as rosette mosaic from Damson to peach. The demonstration of strain differences in both diseases opens up the question still further. Whether or not the virus of rosette mosaic is a strain of prune dwarf virus, the natural occurrence of masked forms of prune dwarf on Damson and its presence in sweet cherry twice and probably three times observed serve to indicate that this disease is more wide spread than has yet been realized.

The author wishes to express his sincere thanks to Dr. G. H. Berkeley for his unfailing interest and many helpful suggestions in connection with this investigation.

SUMMARY

Four viroses have been studied in Ontario, two on plum and two on sweet cherry. Symptomatological evidence is presented that the viruses are strains of prune dwarf virus (Prunus virus 6; *Nanus pruni* H.), differing in virulence. All four strains have been transmitted to at least four varieties of *Prunus domestica*, one of *P. salicina*, two of *P. persica*, one of *P. cerasus*, two of *P. avium*, one of *P. armeniaca*, *P. cerasifera* (Myrobalan), and *P. mahaleb*.

All strains produced typical strap-shaped, rugose, thickened leaves and dwarf growth on Italian prune and Lombard plum; stunting and leaf patterns on peach varieties; and ring, line, and oak-leaf patterns on cherries and *P. mahaleb*. Some plum varieties, namely Reine Claude, German prune, and Grand Duke, showed leaf markings without distortion while some were almost symptomless. Myrobalan was symptomless except with the most virulent strain which induced chlorotic mottles, lines and rings, and sometimes dwarfing.

A tendency to recovery was noted in peaches and cherry varieties after the initial shock symptoms had appeared.

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PHYSIOLOGIC SPECIALIZATION AND THE CONTROL OF MILLET SMUT[1]

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(Accepted for publication July 24, 1944)

INTRODUCTION

Smut, caused by *Ustilago crameri* Keke., is one of the important diseases of millet, *Setaria italica* (L.) Beauv., and is coextensive with the cultivation of the crop. In China, millet is one of the principal food crops, the annual production being approximately 28,675,548,000 pounds (1), and the losses caused by the smut are often of considerable economic importance. Reductions in yield of from 10 to 50 per cent in Northern and Northeastern China are not uncommon (6).

Although millet smut can be controlled effectively by proper seed treatment, obviously it would be more desirable and economical to control it by means of resistant varieties. Most of the common varieties of millet so far tested are susceptible; therefore, selection of lines or the breeding of varieties with suitable agronomic characters and resistance to smut would be necessary. As an aid to the breeding program, it is important to learn the number and geographic distribution of physiologic races of the smut fungus and their pathogenicity on the most important varieties. While the ultimate control of millet smut by breeding resistant varieties is being sought, any control which can give immediate relief, such as seed treatment, also is worthy of attention. Therefore, the relative efficacy of new and old seed disinfectants for the control of millet smut was investigated.

PHYSIOLOGIC SPECIALIZATION IN USTILAGO CRAMERI

Physiologic specialization in certain smut fungi has been known for a long time (2, 9), although it has not been recorded for *Ustilago crameri*. It seemed advisable to determine the reactions of the common varieties of millet to various collections of the millet smut.

Varieties of millet were obtained from the Department of Agronomy, College of Agriculture, Honan University, Honan, China, and from the Division of Agronomy and Plant Genetics, University Farm, St. Paul, Minnesota. All the varieties except German No. 18, German Dark, and Siberian No. 13020, were selfed for several years prior to these tests.

Seed lots were soaked for 8 minutes in 1:250 solution of formaldehyde, covered for 4 hours, washed in water for 4 hours, and then allowed to dry thoroughly. The seed was inoculated by applying an equal amount of dry chlamydospores to each lot of seed, about 0.5 g. of smut spores to 100 g. of seed.

[1] A portion of a thesis presented to the Graduate School, University of Minnesota, June, 1937, in partial fulfillment of the requirements for degree of Doctor of Philosophy. Published as paper 2169 of the Journal Series of the Minnesota Agricultural Experiment Station.

During the winter of 1935, preliminary pathogenicity tests were made in the greenhouse with 5 collections of *Ustilago crameri* on 4 varieties of millet. Although the number of plants inoculated was small, the results indicated clearly that the 5 collections of smut differed in their virulence on 4 varieties of millet. On the basis of these preliminary results, more extensive varietal tests were made with more collections of smut.

In the summer of 1935, 11 varieties of millet were inoculated with 9 collections of *Ustilago crameri*, which were obtained from different parts of China. All the varieties of millet tested were planted at University Farm,

TABLE 1.—*Percentage of smutted heads in 12 varieties of millet inoculated with 9 collections of Ustilago crameri, grown in St. Paul, Minnesota, in 1935 and 1936*

Variety of millet	Year	Percentage of smutted heads[a] with different smut collections									
		5	6	8	9	10	12	13	14	17	Control
German No. 10	1935	0	0	0	0	0	0	19	47	3	0
	1936	0	0	0	0	2	0	4	37	10	0
German No. 18	1935	60	51	52	79	73	71	85	63	55	0
	1936	68	35	47	81	42	65	66	39	70	0
German Dark	1935	33	62	42	90	83	88	24	64	63	0
	1936	47	73	38	82	91	77	40	66	76	0
Hungarian No. 232	1935	50	75	59	86	89	81	52	93	81	0
	1936	57	67	53	77	70	64	68	82	57	0
Kaifeng No. 142	1935	63	73	57	61	83	98	51	100	92	0
	1936	67	84	66	69	68	91	70	87	58	0
Kaifeng No. 232	1935	26	51	33	58	65	0	39	0	0	0
	1936	39	69	21	56	77	2	32	0	0	0
Nanking No. 31	1935	5	7	0	0	1	0	16	14	1	0
	1936	0	13	0	0	16	8	43	6	6	0
Teipien No. 48	1935	44	65	58	56	71	75	40	79	39	0
	1936	57	58	16	35	60	57	44	61	48	0
Unnamed Selection No. 11	1935	83	79	75	86	90	89	57	93	96	0
	1936	68	78	58	53	86	76	59	44	83	0
Unnamed Selection No. 12	1935	48	63	34	59	77	87	8	54	36	0
	1936	74	87	43	64	62	72	26	50	30	0
Siberian No. 1120	1935	68	90	77	82	87	84	60	76	53	0
	1936	63	73	66	70	69	49	50	61	55	1
Siberian No. 13020	1936	6	10	40	2	17	58	31	27	26	0
Race No.		1	1	2	1	1	3	4	5	6	

[a] Percentage computed on number of heads in duplicate rows. (The number of heads in each row ranged from 300 to 400.)

St. Paul, Minnesota, in duplicate 5-foot rows, one foot apart, in a split-plot arrangement. The smut percentages were based on counts of 300 to 400 heads in a row. In 1936 similar tests were made, including an additional variety. The results for the two years' tests are summarized in table 1.

There are striking differences in pathogenicity among the collections of smut. For instance, collection 14 produced no smut on the variety Kaifeng No. 232, but more than 85 per cent infection on the variety Kaifeng No. 142; whereas collection 10 of *Ustilago crameri* caused between 65 and 83 per cent infection on these two varieties.

In general, the pathogenicity of a collection on a particular variety proved to be similar in 1935 and in 1936. Fluctuation in the percentages of smut from one season to another is to be expected, because environmental factors may influence profoundly the development of smuts. It is possible that certain collections of smut consisted of many biotypes that differed greatly in parasitic capabilities and in response to environmental conditions.

In a given year all varieties of millet were grown under parallel conditions; hence differences in their reaction to a smut collection must be attributed to differences in virulence of the latter. This certainly would be true of the test made in 1936, as the inoculum and seed sown were produced and stored under identical conditions and the seed was sown the same day in the experimental plots at St. Paul, Minnesota.

Since each collection of smut in 1936 differed somewhat in parasitism, each one might be considered a physiologic race. This fine distinction seems undesirable and also impractical, however, because of the wide fluctuation in percentages of smut that occurred on the same varieties in different years. Therefore, the determination of races was based on fairly wide differences in pathogenicity.

There are at least 6 distinct parasitic races of *Ustilago crameri* (Table 1). Collections 5, 6, 9, and 10 are classified as race 1, because of their similarity in virulence on the 5 differential hosts: German No. 10, Kaifeng No. 232, Nanking No. 31, Unnamed Selection No. 12, and Siberian No. 13020. Each of the other 5 collections consisted of a different physiologic race. Although the separation of collections into races was more or less arbitrary, consideration was given to variation in smut percentages produced by the same races on a given variety in different replications and in different years. The important point is that there are many races of *Ustilago crameri* that must be considered in breeding smut resistant varieties of millet.

Of course, it is possible that, if further tests were made, certain collections that now appear distinct would be grouped together; also it is possible that certain collections might consist of two or more races. Therefore, the separation of collections into races must be considered of a temporary nature.

All varieties of millet tested were susceptible to certain races of *Ustilago crameri* (Table 1). Although a few varieties were highly resistant to several of the races, most of them were susceptible to 3 or more races. German No. 10 was the most resistant variety tested, while Hungarian No. 232, Siberian No. 1120, and German No. 18 were among the most susceptible varieties and were attacked by all the races.

EFFECTIVENESS OF VARIOUS FUNGICIDES IN CONTROLLING MILLET SMUT

The earliest experiments on the control of millet smut by various fungicides were made by Hecke (3, 4). He used copper sulphate, sulphuric acid, mercury bichloride, and formalin; and, in addition, a hot water treatment. Subsequently, many fungicides were tested by several workers (5, 7, 8). The most promising ones were copper carbonate, formaldehyde dip, and

copper sulphate. New Improved Ceresan, a good fungicide for many cereal smuts, apparently has not been tried.

In studying the effectiveness of various fungicides in controlling millet smut, a moderately susceptible variety, Kaifeng No. 232, which had been selfed for 3 years, was used. The inoculum was a mixture of chlamydospores of the 10 collections of *Ustilago crameri*. Prior to treatment, the millet seeds were cleaned and then artificially inoculated with a mixture of chlamydospores of *Ustilago crameri*. The various fungicides and the rate of application are given in table 2. For each treatment, except formaldehyde solution, the amount of fungicide required was first put in a flask and shaken thoroughly; then the seed was added and the flask was shaken again, until the dust covered the seeds thoroughly. When formaldehyde solution

TABLE 2.—*Results of treating Kaifeng millet with 10 fungicides when seed was inoculated artificially with chlamydospores of 10 collections of Ustilago crameri, in 1935 and 1936*

Fungicide		Year and percentage of infection[b]	
Name	Ounces per bushel	1935	1936
New Improved Ceresan	0.5	0.8	0.4
Formaldehyde dip[a]	.....	1.0	1.1
Cuprocide	2.0	3.6	1.0
Copper carbonate (20 pct.)	4.0	3.1	3.1
Barbak III	2.0	.....	4.6
Kopper's flotation sulphur dust	2.0	5.0	10.9
Powdered sulphur	4.0	.....	15.8
Gas sulphur	2.0	16.6	14.2
Sulphur dust	4.0	23.6	18.8
Formaldehyde dust	3.0	29.7	39.7
Powdered sulphur	2.5	36.2	32.2
Check	0.0	26.9	42.9

[a] The concentration used was 1 part formaldehyde to 250 parts of water.
[b] Results were based on 400–500 heads grown in quadruplicate plots. The minimum level for statistical significance between any two means was 0.74 in 1935 and 1.45 in 1936.

was used, the seed was soaked in the solution for 7 minutes, covered for 5 hours, and then washed and dried in the usual manner.

Nine fungicides were tested in 1935, eleven in 1936. In both seasons, the tests were in triplicate, 10-foot-row plots, replicated 4 times and randomized. The percentages of smut were based on the number of heads infected. The results are in table 2.

In 1935 all fungicides used, except powdered sulphur used at the rate 2.5 oz. per bushel and formaldehyde dust, tended to reduce the percentage of infection, but none of them eliminated smut completely. New Improved Ceresan and formaldehyde dip were more effective than the others, although several other fungicides also were partially effective.

The results in 1936 were similar to those in 1935, except for slight differences. There was no apparent stimulation or increase of the percentage of infection when powdered sulphur and formaldehyde dust were used.

In order to determine the statistical significance of the effectiveness of the different fungicides tested, the data for 1935 and 1936 (Table 2) were analyzed separately by the analysis of variance method. The minimum level for statistical significance between any two means was 0.74 in 1935 and 1.45 in 1936. New Improved Ceresan and formaldehyde dip were the most effective fungicides in 1935; cuprocide and copper carbonate were next. Kopper's flotation sulphur dust was more effective than any other sulphur fungicides.

DISCUSSION

Millet is a food crop which is exceeded in importance in Northern China only by wheat. Smut caused by *Ustilago crameri* is one of the most important diseases of millet. Because of the importance of the crop and the losses caused by this smut, its control is of major importance. While it can be fairly well controlled by certain seed treatments, the development of resistant varieties will be very important in China, where it often is difficult to induce farmers to treat the seed.

Because of the importance of physiologic races of smuts in breeding disease resistant varieties of cereals, the writer investigated the question of physiologic specialization in *Ustilago crameri*. In 1935 eleven varieties of millet were inoculated with 9 collections of smut from China. These collections differed greatly in their pathogenicity. In 1936 the tests were repeated, using one additional variety of millet, and similar differences occurred.

The differences in the reactions to the 9 collections in 1935 and 1936 are not unexpected. Chlamydospore collections may contain many biotypes, and, furthermore, recombinations can be expected. Also, it is well known that differences between biotypes or groups of biotypes may become apparent under some conditions and not under others. In spite of the fluctuation in percentages of smut in certain cases, there are at least 6 distinct parasitic races of *Ustilago crameri*. This fact is of great importance in breeding disease resistant varieties. Although there were great differences in reaction of millet varieties to different races, none of those tried was resistant to all the smut races. Consequently further search must be made for resistant varieties.

SUMMARY

Nine collections of *Ustilago crameri* were tested for their virulence on 12 varieties of millet. Of these, 6 differed sufficiently in pathogenicity on 5 differential hosts to be designated as physiologic races.

Although certain varieties of millet were highly resistant to several races, no variety was resistant to all races.

The prevalence of races of smut must be considered in breeding millet varieties resistant to the disease.

Eleven fungicides were tested as seed disinfectants, and all except powdered sulphur and formaldehyde dust reduced smut. New Improved

Ceresan was very effective; formaldehyde dip, cuprocide, copper carbonate, and Barbak III were fairly effective. In general, sulphur fungicides were not effective.

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PARASITISM OF RHIZOCTONIA SOLANI ON BEANS[1]

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(Accepted for publication July 31, 1944)

In most parts of the United States, and especially in the South where moisture and temperature conditions are favorable, many species of plants are attacked by fungi belonging to the genus *Rhizoctonia*. While these fungi are a heterogeneous group, many of them, because of certain sclerotial characteristics, are considered by most investigators to be *Rhizoctonia solani* Kühn.

That *R. solani* comprises distinct strains differing in morphology, cultural characters, and pathogenicity has been shown by many investigators. Among them are Peltier (12), Rosenbaum and Shapovalov (14), Edson and Shapovalov (2), Matsumoto (9), van der Meer (10), Walker (18), Lauritzen (7), Wiant (19), Gratz (6), Elmer (3), LeClerg (8), Briton-Jones (1), Monteith and Dahl (11), and Sanford (15). The more recent studies of LeClerg (8) and Sanford (17), in which large numbers of isolates from Irish potatoes were tested for pathogenicity on sugar beets, indicated that nearly all were nonpathogenic on this host. These results are of particular interest when certain control problems, such as crop rotation, are being considered.

In Louisiana the common garden bush snapbean, *Phaseolus vulgaris* L., is often attacked by *Rhizoctonia*. Stands are reduced and reddish-brown lesions develop on the stems near the soil surface. As these fungi occur on many hosts other than beans in this State, it seemed desirable to determine if isolates from other hosts were pathogenic on beans.

To obtain this information, a number of isolates were secured from various hosts in Louisiana and from other investigators. Some studies were made of the cultural characters and reactions to temperature of the various cultures, but the major part of the investigations was devoted to a study of their pathogenicity on beans.

ORIGIN OF ISOLATES

From a rather large number of isolates, 27 were finally selected for these studies. Pertinent information regarding them is in table 1.

CULTURAL CHARACTERS

The isolates were compared on bean and potato-dextrose agar. Differences occurred in such characters as the color of the mycelium, rate of growth, and sclerotium formation. A representative group of 6 isolates is shown in figure 1.

[1] Summary of part of a thesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy, granted by the University of Minnesota, August, 1937.

EFFECT OF TEMPERATURE ON RATE OF GROWTH

Twelve isolates from 8 hosts differed considerably in rate of growth on potato-dextrose agar in Petri dishes at 7 different temperatures (Table 2). Only a trace of growth occurred at 6° C. in the isolates from tomato (R7), eggplant (R6), and bean (R76), as compared to 9 to 17 mm. with the other 9 cultures. The optimum temperatures also differed, being from 20° to

TABLE 1.—*Origin of isolates of Rhizoctonia solani*

Number of isolate	Host plant	Part of plant from which isolated	Location	By whom isolated	Date of isolation
R3	Sugar cane	Root	Baton Rouge, La.	E. C. Tims	1932
R4	do	do	do	do	1932
R5	do	do	do	do	1932
R6	Eggplant	Stem base	do	S. Smith	1933
R7	Tomato	do	do	do	1933
R8	Potato	do	do	do	1933
R9	Bean	do	Houma, La.	L. H. Person	1931
R62	Sugar beet	—	Chaska, Minn.	E. L. LeClerg	1930
R64	Bean	Stem base	Houma, La.	L. H. Person	1931
R76	do	do	Baton Rouge, La.	do	1931
R77	do	do	Houma, La.	do	1932
R100	Sugar beet	Seedling	Ohio	E. L. LeClerg	1930
R110	Potato	Tuber (sclerotium)	St. Paul, Minn.	do	1930
R115	do	Stem	Guthrie, Minn.	do	1931
R120	Pea	Root	St. Paul, Minn.	G. H. Starr	—
R127	Potato	Stem	Dilworth, Minn.	E. L. LeClerg	1931
R128	do	do	do	do	1931
R150	Potato	Tuber (sclerotium)	Amherst, Mass.	do	1933
R162	do	do do	Scotts Bluff, Neb.	do	1933
R170	do	do do	Hay Springs, Neb.	do	1933
R178	do	— —	California	do	1933
R188	Rice	Seedling	Welch, La.	D. E. Ellis	1932
R191	Potato	— —	Topeka, Kansas	E. L. LeClerg	1933
R194	Rice	Seedling	Welch, La.	D. E. Ellis	1932
R200	Potato	Tuber (sclerotium)	Kentville, Nova Scotia	E. L. LeClerg	1933
R208	Sugar cane	Stalk (interior)	Baton Rouge, La.	E. C. Tims	1934
R310	Pea	— —	Moscow, Idaho	W. H. Pierce	1935

25° C. for the isolate from potato (R8) and from 25° to 30° C. for the others. Isolates from sugar cane (R4), bean (R9), and sugar beet (R100) grew slowly at 38° C., while the others did not grow.

METHODS USED IN PATHOGENICITY TESTS

For the pathogenicity tests, isolates were grown on a sterile mixture of 4 parts oats and 1 part wheat to which water was added at the rate of 80 per cent by weight. The cultures used for inoculum usually were from 4 to 6 days old when the inoculations were made.

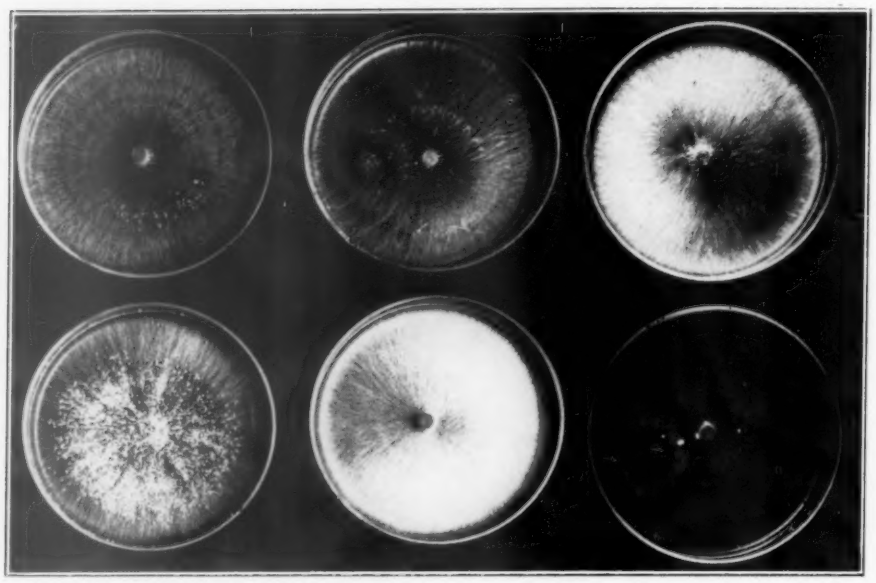

FIG. 1. Six culturally different isolates of *Rhizoctonia solani*.

Inoculations were made in the greenhouse in sterilized soil and in the field. The greenhouse inoculations were of two types: soil inoculation and direct seedling inoculation. The soil was inoculated by mixing approximately 25 grams of the inoculum into 6-inch pots of sterilized soil. After 4 to 6 days the soil was remixed and the seeds were planted one inch deep. Bean[2] seedlings were inoculated directly by removing the soil from the base of the stem and placing the inoculum against the basal-stem portion. The soil was then replaced, covering the inoculum.

Seedlings were inoculated directly in the field similarly to those in the

TABLE 2.—*Effect of temperature on the rate of growth of 12 isolates of Rhizoctonia solani on bean agar (average of 3 tests of 3 replications each)*

Original host	Isolate number	Average diameter of colonies in mm. after 48 hours						
		6° C.	15° C.	20° C.	25° C.	30° C.	34° C.	38° C.
Sugar cane	R4	10	22	37	61	62	54	8
Potato	R8	14	26	36	37	22	11	0
Rice	R194	14	26	43	80	78	69	0
Pea	R120	17	35	51	71	54	23	0
Pea	R310	16	31	49	73	52	26	0
Bean	R9	10	30	47	80	78	57	8
Bean	R64	9	30	51	86	85	43	0
Bean	R76	1	32	50	85	79	48	0
Tomato	R7	1	26	40	69	75	64	0
Eggplant	R6	1	30	47	87	83	66	0
Sugar beet	R62	12	21	35	52	43	23	0
Sugar beet	R100	11	22	39	65	59	43	10

[2] Unless otherwise stated, the term bean refers to bunch snapbeans (*Phaseolus vulgaris*).

greenhouse. For the soil inoculations in the field, the wheat-oats inoculum was mixed with sterilized soil at the rate of 2 quarts to 4 gallons of soil. After two weeks this was mixed thoroughly and dropped into open furrows, 30 grams every 8 inches. The seeds were then dropped into the inoculated hills and covered immediately.

To determine the pathogenicity of the isolates, two methods were used. In one, the percentage stand was used. In the other, an arbitrary scale of infection was used, with 5 classes ranging from 0 to 4. The plants were removed from the soil, washed, and placed in one of the five following infection classes:

0 = No stem lesions (no infection).
1 = One to few small shallow lesions (light infection).
2 = One or several lesions extending into the cortex (moderate infection).
3 = One or more lesions extending deep into the cortex, often completely girdling the stem (severe infection).
4 = Plants killed.

FIG. 2. Infection classes of bean plants inoculated with *Rhizoctonia solani*. Left to right, classes 0, 1, 2, 3.

The average degree of infection for an isolate was then computed by adding the infection class values of individual plants and dividing by the total number of plants. The infection classes 0, 1, 2, and 3 are shown in figure 2.

WOUNDS AND THE PATHOGENICITY OF RHIZOCTONIA ON BEANS

The first experiment, using 24 isolates from 7 hosts, was made in sterilized soil in the greenhouse to learn if wounded bean seedlings were more

TABLE 3.—*Results of inoculating wounded and nonwounded bean plants with 26 isolates of Rhizoctonia solani*

Original host of isolate	Isolates used	Plants not injured		Plants injured	
		No. inoculated	Degree of infection	No. inoculated	Degree of infection
Sugar cane	R3, 4, 5	27	0.00	27	0.00
Potato	R8, 110, 115, 127, 128, 150, 162, 170, 178, 191, 200	102	0.00	98	0.002
Rice	R188, 194	15	0.87	19	1.94
Pea	R120, 310	30	1.46	26	1.88
Bean	R9, 64, 76, 77	37	3.37	38	3.53
Tomato	R7	9	3.44	10	3.60
Eggplant	R6	8	3.63	10	4.00
Averages			1.81		2.14
Control		10	0.00	10	0.00

severely attacked than nonwounded ones. Young plants were wounded by slitting the basal stem portions with a scalpel and an equal number were left unwounded for comparison. The inoculum was placed directly against the stems of injured and noninjured seedlings and covered with soil. Wounding had relatively little effect on the severity of parisitism: the average degree of infection on nonwounded plants was 1.81 and on wounded plants 2.14 (Table 3). The 3 sugar-cane isolates and 11 Irish potato isolates were not pathogenic on either wounded or nonwounded bean plants. The

TABLE 4.—*The degree of infection on 3 varieties of beans inoculated with 14 isolates of R. solani in the field at St. Paul, Minn., 1934*

Original host	Isolate number	Degree of infection[a]			
		Giant Stringless	Bountiful	Webber Wax	Average for 3 varieties
Sugar cane	R4	0.30	0.40	0.50	0.40
Potato	R8	0.15	0.35	0.40	0.30
	R110	0.20	0.70	0.35	0.41
Rice	R194	0.80	0.70	0.85	0.78
Pea	R120	1.35	1.15	1.30	1.27
	R310	1.30	1.05	1.40	1.25
Bean	R9	2.75	2.70	2.70	2.72
	R64	3.25	3.35	3.25	3.28
	R76	2.95	3.15	3.05	3.05
	R77	2.85	2.70	3.25	2.93
Tomato	R7	2.95	3.00	3.00	2.98
Eggplant	R6	2.05	2.45	3.05	2.52
Sugar beet	R62	3.30	3.30	3.45	3.35
	R100	2.95	2.90	3.10	2.98
Control		0.10	0.15	0.25	0.17

[a] Average of 2 tests of 3 replications each.

others differed in pathogenicity, ranging from an average degree of infection of 1.41 for the rice isolate (R194) to 3.83 for the eggplant isolate (R6). The wounded plants wilted 1 to 2 days earlier than the nonwounded ones. This agrees with the results of Fulton (5), who reported that Rhizoctonia-infected noninjured plants wilted as frequently but not so quickly as slightly injured plants.

FIG. 3. Beans inoculated with *Rhizoctonia solani* in the field at St. Paul, Minn. The row on extreme left is a check. The 2 center rows from left to right were inoculated with isolates R76 and R64, respectively. The row on extreme right was inoculated with isolate R110.

PATHOGENICITY OF RHIZOCTONIA ON BEANS IN THE FIELD

Seeds of 3 varieties of beans, the Giant Stringless, Bountiful, and Webber Wax, were planted in the field at St. Paul, Minn., and, after emergence, the seedlings were inoculated directly. The soil was removed from around the stems of the plant and the inoculum applied, after which it was covered with soil. The results (Table 4) were essentially the same as in the earlier test in sterilized soil. The sugar-cane isolate (R4) and the 2

potato isolates (R8 and R110) were not pathogenic. The rice isolate (R194) was slightly pathogenic; the pea isolates (R120 and R310) were somewhat more pathogenic than the rice isolate; and the four from bean, the tomato, the eggplant, and 2 sugar-beet isolates were very pathogenic to all 3 bean varieties. This difference in pathogenicity is shown in figure 3. A similar test was made at Baton Rouge with the Giant Stringless, Bountiful, and Sure Crop Wax varieties. The results were essentially the same.

In 2 tests with the same varieties of beans and with the same isolates, the soil was inoculated and the bean seed planted immediately. The percentage stand of beans in the soil inoculated with each isolate is given in table 5. It may be seen that the isolates again differed in their patho-

TABLE 5.—*Percentage stand of 3 varieties of beans in field soil inoculated with 14 isolates of Rhizoctonia solani at St. Paul, Minn.*

Original host	Isolate number	Stand in per cent[a]		
		Giant Stringless	Bountiful	Webber Wax
Sugar cane	R4	91	89	88
Potato	R8	92	92	86
	R110	89	89	85
Rice	R194	16	21	10
Pea	R120	82	92	85
	R310	92	89	86
Bean	R9	92	90	82
	R64	86	86	77
	R76	89	89	79
	R77	92	89	83
Tomato	R7	87	85	84
Eggplant	R6	86	84	76
Sugar beet	R62	54	68	47
	R100	56	62	36
Control	.....	92	93	86

[a] Average of 3 replications of 104 seeds each.

genicity. The rice isolate (R194) was the most pathogenic of all isolates, decreasing stands of all three varieties. It had been only moderately pathogenic, however, when the size of lesions on the stem was used as a criterion (Table 4). The sugar-beet isolates (R62 and R100) were next in pathogenicity, reducing stands considerably. The sugar-cane (R4) and potato (R8 and R110) isolates did not reduce emergence. An analysis of variance using the method given by Fisher (4) was also made of these data. Highly significant differences (exceeding 1 per cent point) existed in the relative pathogenicity of the isolates and the reactions of the three varieties to the isolates.

PATHOGENICITY OF RHIZOCTONIA ON BEANS AND OTHER LEGUMES IN THE GREENHOUSE

Beans.—Experiments in sterilized soil in the greenhouse under more rigidly controlled conditions also served to test the various isolates as to their

pathogenicity on beans. The results with 25 isolates from 8 hosts are in table 6. The 3 sugar-cane isolates, the 11 potato isolates, and the 2 pea isolates had no effect on the stand of beans. The rice isolate (R194), as in previous tests, almost completely prevented emergence of the bean seedlings. The 4 bean isolates, the tomato isolate, the eggplant isolate, and 2 sugar-beet isolates reduced stands considerably.

Other Legumes.—As the field and greenhouse tests indicated that the various isolates could be separated into 4 groups, based on their patho-

TABLE 6.—*Percentage stand of beans in sterilized soil inoculated with 25 isolates of Rhizoctonia solani*

Original host	Isolate number	Number of tests	Number of seeds	Stand in per cent
Sugar cane	R3	1	24	88
	R4	2	124	87
	R5	2	124	95
Potato	R8	4	324	90
	R110	4	324	94
	R115	3	224	92
	R127	3	224	89
	R128	3	224	90
	R150	3	224	93
	R162	3	224	90
	R170	3	224	89
	R178	3	224	90
	R191	3	224	88
	R200	1	24	96
Rice	R194	2	124	5
Pea	R120	2	124	94
	R310	2	124	92
Bean	R9	2	124	65
	R64	2	124	76
	R76	4	324	52
	R77	2	124	52
Tomato	R7	2	124	50
Eggplant	R6	2	124	39
Sugar beet	R62	2	124	46
	R100	1	100	64
Control	.....	4	324	89

genicity on beans, further experiments were made with several additional species of plants. The tests were in sterilized soil in the greenhouse and the hosts were soybeans, English peas, cowpeas, broadbeans, and beans. Thirteen isolates from 8 hosts were used. The results (Table 7) indicate that the sugar-cane isolate (R4) and the potato isolates (R8 and R110) which had been nonpathogenic on beans were not pathogenic on soybeans (*Soja maxima* L.), English peas (*Pisum sativum* L.), cowpeas (*Vigna sinensis* Endl.), and broadbeans (*Vicia faba* L.). The rice isolate (R194), which was highly pathogenic on snapbeans, also was very pathogenic on English peas, cowpeas, and broadbeans, but was not so pathogenic on soybeans (34 per cent stand as compared to 49 per cent stand in control). The 2 pea isolates (R120 and R310), which were equally pathogenic on beans

and reduced stands very little, differed in their effects on the other hosts. R310 was somewhat pathogenic on soybeans, while R120 was not. On English peas and broadbeans R310 was much more pathogenic, almost completely preventing emergence. On cowpeas there was little difference between the 2 isolates, both reducing stands somewhat. The 3 bean isolates (R9, R64, and R77), the tomato isolate (R7), the eggplant isolate (R6), and the 2 sugar-beet isolates (R62 and R100), in previous tests on beans, had about the same pathogenicity range, reducing stands somewhat; but they differed on soybeans, English peas, and cowpeas, the sugar-beet isolates being less pathogenic on soybeans and English peas than the others, and

TABLE 7.—*Percentage stands of 5 leguminous hosts in sterilized soil inoculated with 13 isolates of Rhizoctonia solani*

Original host	Isolate number	Stand in per cent[a]				
		Bean	Soybean	English pea	Cowpea	Broadbean
Sugar cane	R4	93	51	90	91	80
Potato	R8	88	47	85	89	70
	R110	94	49	92	93	90
Rice	R194	4	34	12	1	0
Pea	R120	83	44	60	76	90
	R310	82	24	1	69	0
Bean	R9	52	1	2	28	0
	R64	78	13	3	27	0
	R77	56	8	1	28	0
Tomato	R7	46	5	3	47	0
Eggplant	R6	61	19	1	9	0
Sugar beet	R62	57	31	68	93	0
	R100	58	41	54	91	0
Control	.....	93	49	93	91	80

[a] Figures for broadbean were obtained in one test; those for cowpea are averages of 2 tests; those for other crops are averages of 3 tests.

nonpathogenic on cowpeas. The tomato isolate could possibly be distinguished from the bean and eggplant isolates in that it was less pathogenic than they were on cowpeas. All isolates from bean, tomato, eggplant, and sugar beets prevented emergence of broadbeans.

EFFECT OF ENVIRONMENT ON PATHOGENICITY

To determine the effect of temperature on the pathogenicity of the isolates on beans, seeds were planted in inoculated sterilized soil held at various temperatures. Seven isolates were tested and the percentage stand of beans was used as the criterion of pathogenicity. The isolates were pathogenic from 15° to 28° C., being most pathogenic at the lowest temperature (Table 8). These results agree with those of Richards (13) and Sanford (16). The potato isolate (R8) used was not pathogenic at any of the 3 temperatures.

A test was then made to determine the effect of soil moisture on the emergence of bean seedlings in soil inoculated with various isolates of *R. solani*.

TABLE 8.—*Effect of soil temperature on the pathogenicity of 7 isolates of Rhizoctonia solani on beans*

Original host	Isolate number	Stand in per cent[a]			
		15° C.	20° C.	24° C.	28° C.
Potato	R8	68	78	.....	60
Control	.....	70	75	.....	70
Rice	R194	7	2	0	.....
Bean	R9	0	0	.....	25
	R64	64	76	73	.....
	R76	25	53	45	55
	R77	47	53	60	.....
Sugar beet	R62	7	13	11	.....
Control	.....	76	78	89	80

[a] Based on 40 seeds at each temperature for each isolate.

Seven isolates and 3 moisture contents were used. Stands were reduced about equally at the 3 soil moistures but the average degree of infection was more severe at 60 and 80 per cent soil moisture than at 40 per cent (Table 9).

EFFECT OF AMOUNT OF INOCULUM ON PATHOGENICITY

Isolate R194 from rice was so pathogenic on beans when seeds were planted in inoculated soil, almost preventing emergence in the various tests, that a special study was made to determine if the amount of inoculum was responsible for the severity of its attack.

In 4 experiments the amount of inoculum was varied. In 2 tests the amount of oat-wheat inoculum varied from 50 g. to 2 g. per 6-inch pot. Seeds were planted in half the pots immediately after inoculation and in the other half 4 days later. In the other two tests, 25 g. of inoculum were added to each 6-inch pot. After 4 days the inoculated soil was removed and thoroughly mixed. This mixture was then added to sterilized soil in the following proportions by weight: 1:0, 3:1, 1:1, 1:3, 1:7, and 1:15.

TABLE 9.—*Effect of soil moisture on the pathogenicity of 7 isolates of Rhizoctonia solani on beans*

Original host	Isolate number	Moisture content in per cent					
		40	60	80	40	60	80
		Stand in per cent[a]			Degree of infection		
Potato	R8	83	93	60	0.00	0.04	0.00
Rice	R194	0	0	0	.....	.....	.....
Pea	R310	92	88	67	0.64	0.38	1.05
Bean	R9	63	52	25	0.34	1.87	1.20
	R76	88	68	28	0.58	1.71	1.41
Eggplant	R6	65	40	47	0.95	1.38	1.54
Sugar beet	R100	65	58	48	0.46	0.80	1.17
Control	.....	99	90	65	0.00	0.00	0.00

[a] Based on 60 seeds for each isolate at each temperature.

TABLE 10.—*Results of soil inoculations with different amounts of inoculum of isolate R194 showing percentage emergence of beans*

Time of planting seed	Emergence in per cent[a]						
	Amount of inoculum (in grams) added to each 6-in. pot of soil						
	50	32	16	8	4	2	Control
Four days after soil inoculation	0	2	0	3	0	0	94
At time of soil inoculation	0	0	0	0	0	0	98
	Ratio of inoculated to noninoculated soil						
	1:0	3:1	1:1	1:3	1:7	1:15	Control
Three days after soil inoculation	0	0	0	0	0	0	93
At time of soil inoculation	5	4	2	5	4	1	95

[a] Based on 5 replications of 20 seeds each.

The same procedure was followed in planting, half the pots being planted at the time of inoculation and the remainder 3 days later. The results (Table 10) show that neither the amount of inoculum nor the time of planting had any effect on the degree to which the fungus prevented emergence.

PARASITISM OF ISOLATE R194 ON BEAN SEEDLINGS

A test was made using 12 pots of soil inoculated with cultures of R194 and 12 pots, as controls, in which only the sterile oat-wheat mixture was

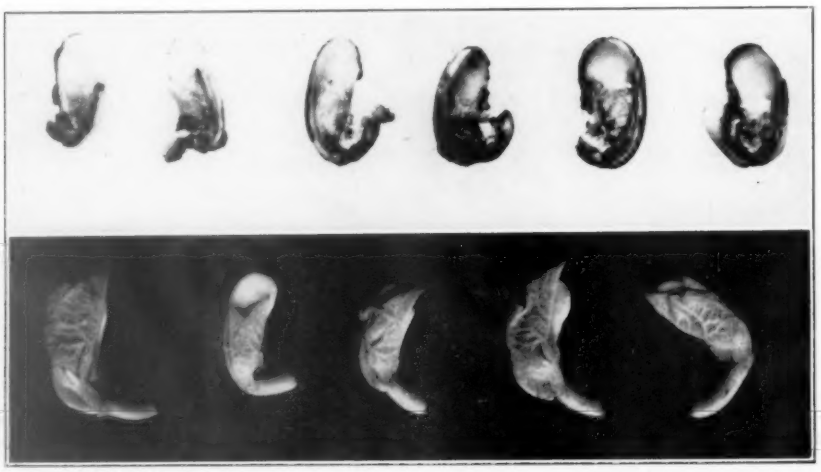

FIG. 4. Effect of *Rhizoctonia solani* isolate R194 on bean seed. Top: Seed planted in inoculated soil. Bottom: Seed planted in sterilized soil.

added to the soil. Fifteen bean seeds were planted in each pot and 4 days later the seeds were removed from 1 pot of inoculated soil and 1 pot of control soil. In the control soil the 15 seeds had germinated while in the inoculated pot 4 seeds had germinated. The seed coats from the inoculated soil were covered and penetrated by the mycelium of the fungus and the radicles were attacked where they emerged from the cotyledons (Fig. 4). Two days later another inoculated and another control pot were examined. All 15 seeds had germinated in the control, and 10 in the inoculated soil. Only a slight elongation of the hypocotyl, however, had taken place in plants from the inoculated soil. Each hypocotyl was infected at the point of emergence from the seed and the plumular leaves were dark brown. Rhizoctonia mycelium occurred in the plumules. Eight and 10 days after planting, inoculated and control pots were again examined and the seedlings were similar to those previously examined. In the 6 inoculated pots remaining, 26 days after planting, no seedlings had emerged, while 82 healthy plants were in the 6 control pots.

DISCUSSION AND SUMMARY

Rhizoctonia solani can cause damping-off and stem rot of beans under a rather wide range of temperature and soil moisture content. The isolates studied comprise a number of strains differing in cultural characters and rate of growth at different temperatures.

When beans were used as the test host, 4 rather clear-cut groups of isolates were distinguished on the basis of pathogenicity: (1) isolates from sugar cane and from sclerotia found on Irish potato tubers, which were not pathogenic on beans; (2) isolates from peas, which caused only a very slight amount of damping-off and only a moderate stem infection; (3) the isolate from rice, which almost completely prevented emergence but caused less severe stem lesions than the pea isolates; (4) isolates from bean, tomato, eggplant, and sugar beet, which were capable of reducing stands somewhat and caused very severe lesions on stems. The isolates in groups (2) and (4) could be further subdivided when cowpeas, English peas, soybeans, and broadbeans were added as differential hosts.

The nonpathogenicity of the sugar-cane and potato isolates is of interest and may be of possible importance when considering the rotation system in the alluvial sections of Louisiana. These hosts are important economic crops in some of these areas.

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SAPSTREAK, A NEW KILLING DISEASE OF SUGAR MAPLE

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(Accepted for publication July 31, 1944)

INTRODUCTION

In the fall of 1939, attention was called to an unusually heavy mortality among large sugar maples (*Acer saccharum* Marsh.) in the Big Ivy section of the Pisgah National Forest, near Barnardsville, N. C. Local residents reported this dying to have been taking place since about 1935. The Big Ivy working circle of the forest supports, in part, a stand of old-growth northern hardwoods, including about 4 million board feet of virgin sugar maple of very high quality. In the mountains of North Carolina, as a whole, the Forest Survey of the U. S. Forest Service estimates that there are approximately 54 million board feet of sugar-maple sawtimber.

Surveys by Mr. A. H. Maxwell, then with the Pisgah National Forest, and the author, indicated that the new disease, sapstreak, was restricted to a few neighboring creek drainages. About 60 trees were dead or dying along Corner Rock Creek, and about a dozen more were scattered in the other drainages. As of 1943, the disease seems to be confined to the area delimited by these drainages, although sugar maple occurs abundantly over wide areas contiguous to the affected areas.

SYMPTOMS

Ordinarily 3 or 4 years elapse between the first crown symptoms and death of a tree from sapstreak. In occasional cases, affected trees died suddenly when in full leaf. Although the development of the disease has not been followed in detail, certain of its characteristics are obvious and outstanding. The first external symptom is usually a dwarfing of the foliage to about half normal leaf size, causing the crowns to look thin. A slight chlorosis usually accompanies this dwarfing. The next year the upper part of the crown starts to die (Figs. 1, A, and 2, A), and within another year or two the entire tree may die. One large tree was dead within a year of the time the first thinning of the foliage was noted, while other trees have been known to remain alive 4 years after first showing symptoms.

The trunk wood becomes watersoaked in wide radial streaks from the inner sapwood into the outer sapwood, sometimes to the cambium, looking much like figure 1, C, of the paper by Davidson and Campbell (3) on a gall of sugar maple. This watersoaking approaches nearest the cambium in the lower part of the trunk. There are often green streaks at the margins of the watersoaked areas, and in the middle of the watersoaked "fingers" are always narrow streaks, reddish or gray when the wood is moist and gray

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when it is dry. The watersoaking and the gray streaks in the trunk always accompany decline of the crowns. Wherever the watersoaking reaches the cambium, this tissue is killed at the points of contact. In the few cases in which entire trees were cut into sections for examination, the watersoaking had developed from the base of the tree upward, and disappeared at a height of 20 to 40 feet.

Sapstreak has not been found in trees under 8 inches in diameter, at breast height, and no intermixed red maples (*Acer rubrum* L.) have been found affected. The roots of one large dying sugar maple were excavated. Portions of the root system were dead, as was to be expected in trees of great

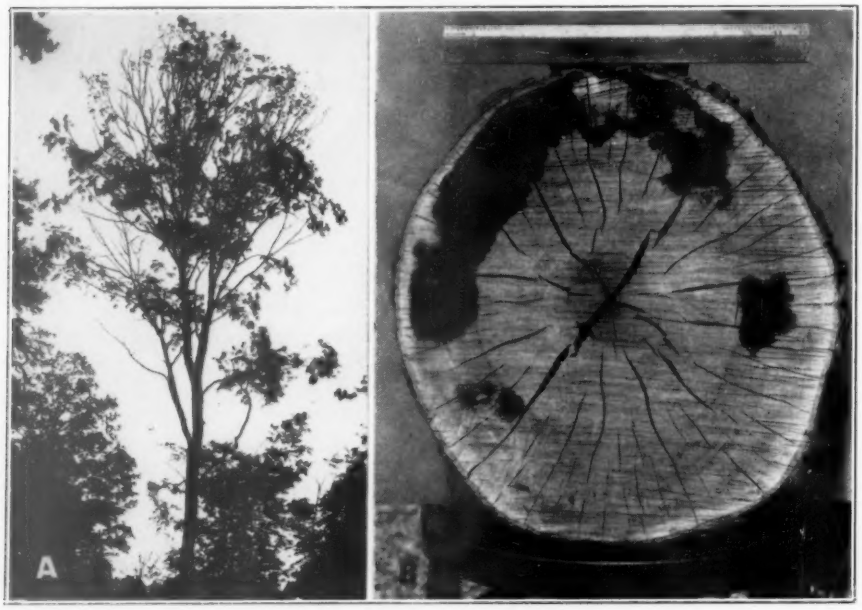

FIG. 1. A. Naturally infected sugar maple showing dying of the upper crown, a typical early external symptom of the sapstreak disease. B. Section from a naturally infected trunk 37 feet above ground, showing the discoloration by *Endoconidiophora virescens*.

age. Gray streaks and watersoaked areas were abundant in some of the larger roots, and seemed to have developed where large roots had died. Rhizomorphs and mycelial fans of *Armillaria mellea* were abundant on the dead roots, a condition common to the roots of many hardwoods of advanced age in this region. A *Xylaria* was also associated with some of the dead roots, and *Ustulina vulgaris* was causing some of the decay in dead roots.

ISOLATIONS

About 200 isolations, on both malt and Bacto-peptone agars, have been made from various tissues. Only one organism, *Endoconidiophora virescens* Davidson, has been consistently isolated from the discolored wood of the trunk. *E. virescens* had been included under *E. coerulescens* until David-

son, in a recent paper (2), recognized and described this American fungus as distinct from the European *E. coerulescens*. The maple sapstreak fungus was identified both by R. W. Davidson and C. T. Rumbold, and has been previously reported only as a cause of blue-stain in hardwood logs and lumber, and occasionally behind injuries in both hardwoods and softwoods.

Cultures prepared from the watersoaked or green-streaked tissue surrounding the reddish or grayish radial streaks generally yielded either no organisms or occasional bacteria of different kinds. Almost invariably, however, when the implanted tissue included a bit of a gray or reddish streak, the culture yielded *E. virescens*. This indicates that we may regard the watersoaking and green streaks as host responses to the presence of the fungus in certain adjacent elements.

E. virescens has been consistently isolated from the internal streaks in a large number of diseased trees. In one tree the highest sapwood discoloration, at a height of 40 feet, occupied less than half the circumference of the sapwood and the inner bark was alive; and the fungus was isolated. The discoloration and watersoaking in the first 10 feet of the trunk involved the entire circumference of the outer sapwood, and all of the inner bark to this height was dead and brittle. The foliage of the tree had died a few months previously. Figure 1, B, shows a section taken at a height of 37 feet that was set face down on the laboratory floor for 4 days to bring out the infection pattern of the fungus. The internal nature of the infection can plainly be seen since a band of uninvaded normal sapwood separates the stained portions from the cambium almost all the way around.

The pH of sugar maple wood is normally in the vicinity of 5.5. Freshly cut wood in the watersoaked areas, had a pH of 8.5 or above, as determined by the Hellige Triplex indicator applied directly to the wood.

INOCULATIONS

Since *E. virescens* was generally associated with the trunk symptoms, inoculations were made in the stems and roots of sugar maples, using single-spore cultures of this fungus. The trees inoculated in April, 1940, ranged from 17 to 34 inches in diameter at breast height, and were in the locality where other trees had been diseased, although no trees had died of sapstreak on the small tract selected.

The fungus was grown on rye and introduced into trees by the following methods: (1) in 3 bore holes about 3 inches deep made with a $\frac{3}{8}$-inch auger, arranged more or less equidistant around a tree at breast height, (2) in 1 bore hole in each of 2 roots near the base of a tree, (3) in a pocket about 6×6 inches gouged out of the stem at breast height, holding the inoculum in the pocket by a large rubber patch, (4) in similar pockets gouged out of 2 roots. Three trees were inoculated by each method, and, using sterile rye, one check tree was prepared for each method.

Table 1 gives the results of these inoculations, and figure 2 shows two of the inoculated trees 3 years after inoculation.

TABLE 1.—*Results of inoculation of sugar maple with Endoconidiophora virescens*

Inoculation method	Total trees	After 2 years			After 3 years			
		Normal	Diseased	Dead	Normal	Diseased	Dead	Total infected
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Stem								
Bore holes	3	2	1	0	2	0	1	1
Poultices	3	3	0	0	2	1	0	1
Checks	2	2	0	0	2	0	0	0
Root								
Bore holes	3	2	1	0	1	2	0	2
Poultices	3	0	2	1	1	1	1	2
Checks	2	2	0	0	2	0	0	0
All inoculated	12	7	4	1	6	4	2	6
All checks	4	4	0	0	4	0	0	0

Both stem and root inoculations, using either the bore-hole or poultice method, resulted in extensive infection in one or more trees. At the end of 3 years, of 12 trees inoculated, 2 were dead, and 4 others were obviously diseased. Figure 2, A, shows a tree inoculated by means of a stem poultice. Its crown has become very thin, at the end of the third year, and the tree will doubtless die within a year. Figure 2, B, shows a tree that was inoculated

FIG. 2. A. An 18-inch sugar maple inoculated by stem poultice 3 years before this photograph was taken. The crown is still alive but has thinned considerably. B. A 20-inch tree inoculated through three auger holes 3 years earlier. This tree was a perfect specimen when inoculated and was dead 3 years later.

through three bore holes. It was a vigorous tree when inoculated, had dwarfed foliage after 2 years, and was dead at the end of 3 years. Figure 3, A, shows the streaking that developed from one of the bore holes in the tree shown in figure 2, B, by the end of the second year, while the tree was still alive.

None of the check trees, representing all types of inoculation, but receiving sterile rye as inoculum, have become diseased, nor have any of the many untreated sugar maples among the treated trees on this tract become diseased.

Endoconidiophora virescens has been reisolated from the streaks in the three inoculated trees cut into for this purpose. The results of the inoculations have been striking enough to warrant careful study of the disease, including inoculation experiments with small saplings, in which the development of the pathogen can be more readily followed.

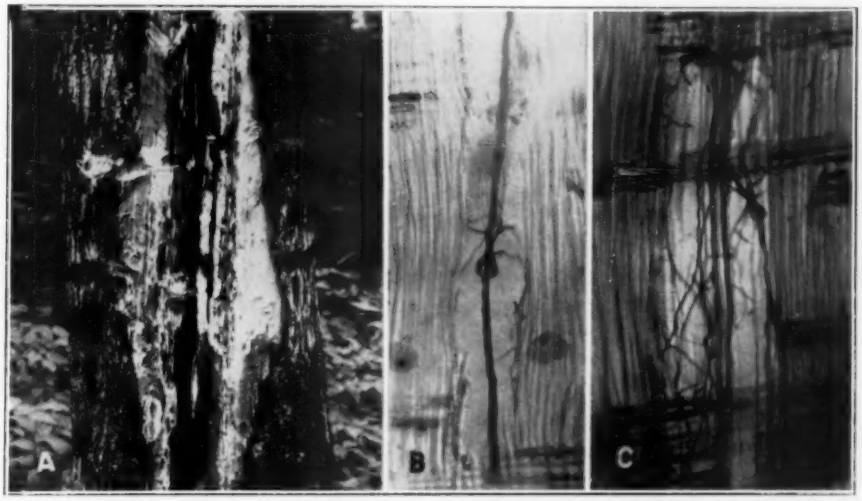

FIG. 3. A. Extensive streaking of the sapwood of the tree shown in figure 2, B, two years after inoculation. The inoculation hole is in the center of the picture. B. Large hypha of *Endoconidiophora virescens* in a vessel, bearing a lyre joint. C. Mass of hyphae in vessels, one of which bears a lyre joint.

From the manner in which the gray streaks radiate outward, it appears as though the fungus establishes itself in the inner sapwood of the trunk, possibly coming up from dead roots, and works outward. Death of the surrounding ray and wood parenchyma cells by toxin production or breakdown of conduction by invaded elements may cause the watersoaking, and the occasional green streaks seem to be a host reaction common in living maple wood induced by the presence of certain organisms. Green streaks also occur with the maple wilt *Verticillium*, and have been found in other cases of organic irritation of maple sapwood (3).

THE CAUSAL FUNGUS

Endoconidiophora virescens, under the name *E. coerulescens*, has been reported as one of the most prevalent fungi causing sap stain in hardwood

logs and lumber in the United States (1, 2, 5, 6), occurring also occasionally on pine. That a fungus with such a habitat should also be able to develop luxuriantly in the living sapwood of a vigorous sugar maple, spreading rapidly through this tissue and killing the tree, is most unusual. Lagerberg, Lundberg, and Melin (4) describe spread of the closely related *E. coerulescens* from blazes made on living spruces, to over 10 feet longitudinally and 1.3 inches in depth, in 20 months. Even in these cases, however, there was no general spread through the sapwood, such as takes place with *E. virescens* in sugar maple. Some members of the closely allied genus *Ceratostomella* are active parasites, such as *C. ulmi* and the fungus that causes the canker-stain disease of the plane tree (7). Neither of these fungi, however, generally occur as sap-stainers of logs and lumber. Culturally the fungus causing sapstreak of sugar maple agrees closely in color, odor, and morphology, with *E. virescens* isolated from stained yellow-poplar logs and lumber.

TABLE 2.—*Comparison of isolates of Endoconidiophora virescens after 14 days in Petri plates of malt agar*

Characteristic	Isolate number[a]			
	1	2	3	4
Sweet, musty odor	Strong	Mild	Strong	Strong
Perithecia	Rudiments	None	Abundant	Few
Sphaeroid endoconidia	Abundant	None	Abundant	Abundant
Rod-shaped endoconidia	Abundant	Mod. abundant	Abundant	Abundant
Growth rate[b]	Rapid	Slow	Rapid	Moderate

[a] Culture 1—From sap stain in yellow poplar log.
" 2—From inoculated sugar maple. Deteriorated culture.
" 3—From surface lumber stain, yellow poplar. Fresh isolate.
" 4—From naturally diseased sugar maple. Fresh culture.

[b] Slow —Colony 9 centimeters in diameter after 7 days at room temperature.
Moderate— " " " " " " 6 " " " " " .
Rapid — " " " " " " 4 " " " " " .

Both fungi are highly variable in culture, especially old cultures. A culture of the sugar-maple sapstreak fungus isolated from an inoculated tree grew profusely in culture when first isolated, had a strong, sweetish, musty odor, and sporulated abundantly. After a year in the refrigerator, fresh agar plantings grew much slower, had less odor, and sporulated much less. Davidson (2) mentions variability and sectoring in *E. virescens*. Table 2 compares four isolates, two from diseased sugar maple and two from yellow poplar sap-stained after felling.

The cultures listed in table 2 have been used in new inoculations to determine whether isolates from sap-stained lumber will cause the sapstreak disease. The determination of the potentialities and means of control of sapstreak will depend to a large extent on whether or not the lumber-stain and sugar-maple sapstreak fungi are identical physiologically.

The hyphae of *E. virescens* are generally confined to the vessels, and in this way differ sharply from the conifer sap-stain Ceratostomellae that normally live in the rays. Hyphae of the sapstreak fungus are brown and

develop copiously in the vessels and rarely in the rays. The larger hyphae branch peculiarly at some of the septa, often producing a structure in the shape of a lyre, for which the name "lyre joint" is proposed (Fig. 3, B and C). Lyre joints form only at a septum. One side branch or two opposite side branches may form. These branches are usually short, and come to a tapering point. Sometimes they grow long and may branch farther. Each side branch bears a septum just above the point of anastomosis with the main hypha. The two opposite branches bending inward toward the main hypha just beyond the point of anastomosis give them a lyre-like appearance, but sometimes they are not incurved. Lyre joints have been found abundantly both in diseased maple wood and in sap-stained yellow-poplar lumber. A search for similar structures in wood stained by other fungi is being conducted. Lagerberg, Lundberg, and Melin (4) do not mention the occurrence of lyre joints in their description of the closely allied *E. coerulescens,* nor have they been reported for other fungi.

SIGNIFICANCE OF THE DISEASE

A close watch is being kept on the development of the disease in the affected area. Notes were taken in 1941 on the condition of 6 trees, along the truck trail through the area, that showed slight evidence of crown thinning. In 1943, two of these were dead, the others had become much worse, and some new cases could be seen from the road.

A 13-acre plot containing 78 large sugar maples, two of which were diseased, was established in the affected area in 1941. In 1943, the two diseased trees were dead, and one additional tree had crown symptoms.

Any disease that works so rapidly that a 20-inch tree can be killed in 3 years by inoculations in three small holes in the trunk, must be considered potentially dangerous. A large volume of valuable sawtimber in the Big Ivy section is already diseased. It remains to be seen whether or not the disease is increasing in amount from year to year in the affected area, and if it is spreading to other areas. The Forest Service is harvesting the diseased timber now before it dies and every effort is being made to salvage as much of this material as possible.

SUMMARY

A disease of sugar maple, for which the name "sapstreak" is proposed, has been killing large numbers of trees in a part of the Pisgah National Forest, near Asheville, N. C.

Healthy sapwood of vigorous trees is invaded by a strain of the fungus *Endoconidiophora virescens,* which produces gray to reddish radial streaks and watersoaked areas in the wood. The foliage becomes progressively smaller and paler green each year, and death usually occurs within 2 to 4 years from the first evidence of crown-thinning.

Inoculation of 12 large trees with *E. virescens* resulted in 2 dying and 4 becoming heavily diseased, in 3 years.

The causal fungus is morphologically indistinguishable from the common sapstain fungus on hardwood lumber, earlier referred to *E. coerulescens*, and recently renamed *E. virescens*.

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MACROPHOMINA ROOT AND STEM ROT AND ANTHRACNOSE OF CHAMAECRISTA[1]

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(Accepted for publication August 17, 1944)

Chamaecrista procumbens (L.) Greene and *C. fasciculata* (Michx.) Greene, commonly known as partridge pea or sensitive pea, are low, woody annuals that grow wild along highways and in waste places in many parts of southeastern United States. Since they are able to survive such adverse conditions, these plants have been studied by scientists of the Soil Conservation Service, United States Department of Agriculture, to determine their usefulness in preventing soil erosion. Investigators have found that considerable numbers of plants in Soil Conservation Nurseries and elsewhere are killed by diseases. The present investigations have determined 2 causes of the death of these plants.

In September, 1941, the writer visited the Soil Conservation Nursery at Thorsby, Alabama, to inspect dying plants of *Chamaecrista.* Large plants of both species were being killed: *Chamaecrista procumbens* was affected by a root rot, the cause of which was not immediately evident, whereas *C. fasciculata* was dying from injury to the stem near the surface of the soil produced by the larva of a snout weevil.[2] This insect injury was later found to be prevalent in plants growing along highways in Georgia.

A survey for diseases that might limit the usefulness of the partridge pea in a soil-erosion program has revealed the existence of an anthracnose that is potentially capable of destroying or damaging many plants. The root rot and the anthracnose have been studied and the results obtained are reported in this paper.

ROOT ROT

Symptomatology

A fairly high percentage of plants of *Chamaecrista procumbens* growing in rows in the nursery at Thorsby were dead or dying. The tops of some of the plants were somewhat wilted, others were brown and dead. The plants appeared to have been affected over a considerable period of their life cycle, since there were varying degrees of stunting, the upper nodes often were shortened somewhat, and the leaflets were small, giving the ends of many branches a rosetted appearance and suggesting the presence of a virus (Fig. 1). The roots had a dark-brown rot and some were badly disintegrated. There was no fungus fruiting on the surface and no other clue to the cause of the disease was observed at the time.

[1] Cooperative investigations between the Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, and the Georgia Agricultural Experiment Station. Paper number 127, Journal Series, Georgia Agricultural Experiment Station.

[2] Determined as *Contrachelus carolinensis* Schoof by H. F. Schoof, Raleigh, North Carolina.

Isolation of the Pathogen

A number of diseased plants with different types of symptoms were taken to the laboratory and several isolations were made from the roots, stems, and twigs. Some plants were placed in a can of water and held at room temperature for about 3 weeks for further observation.

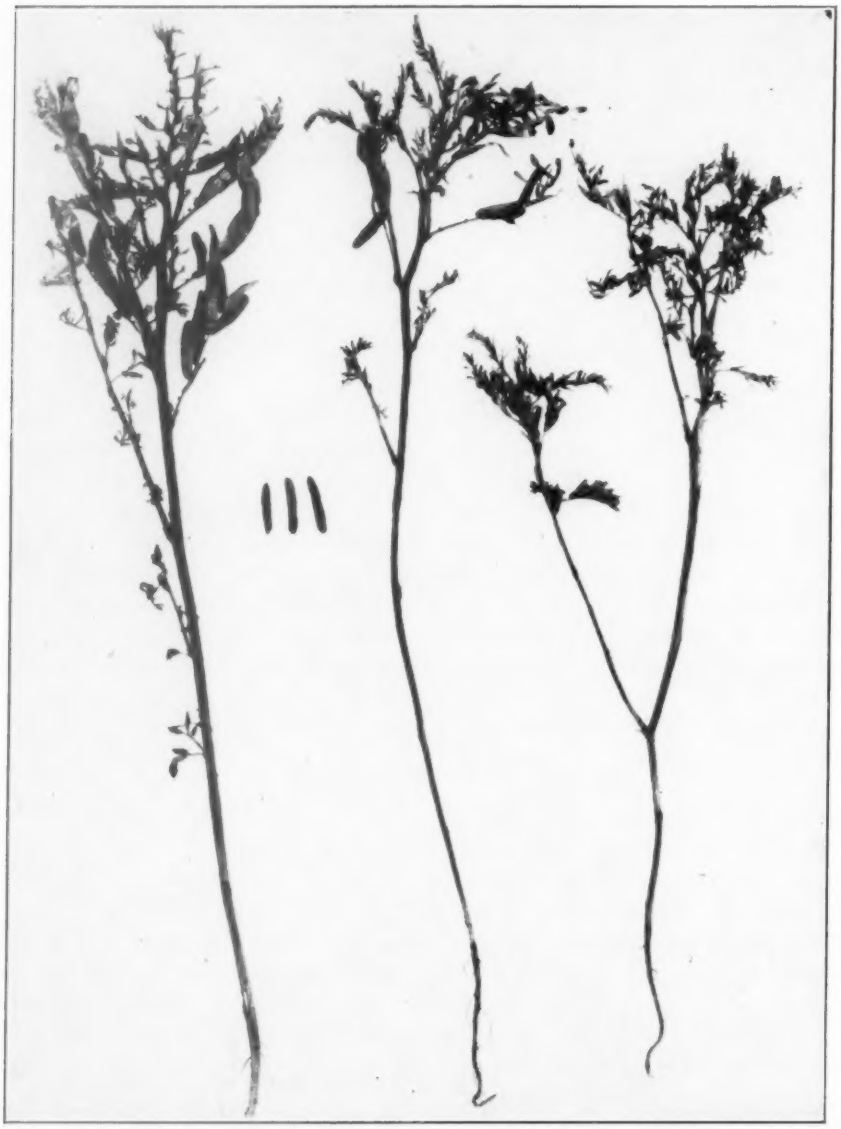

FIG. 1. Plants of *Chamaecrista procumbens* attacked by *Macrophomina phaseoli*. Naturally infected plants from Thorsby, Alabama, with tops greatly stunted and tap and fibrous roots badly decayed. $\times \frac{2}{3}$.

A sclerotium-producing fungus was isolated from 5 of 9 twigs, from 4 of 6 stems, and from 2 of 6 roots. Other fungi were isolated, some of which

failed to fruit and were not identified, and on some plates only *Aspergillus sp.* appeared.

After the plants had been held with their roots in water for a week or longer, many large pycnidia appeared on their stems, usually on the 2½ inches between the top of the water and the top of the container. These pycnidia contained rather large, ovoid, hyaline, unicellular spores.

The fungus was in the tissue of practically all diseased plants and readily produced sclerotia and pycnidia on host tissue and formed sclerotia in culture. It was identified as *Macrophomina phaseoli* (Maub.) Ashby and was the cause of root rot and death of the plants.

The fungus from *Chamaecrista* was compared with isolates from other hosts but no consistent difference was found. A culture from *Chamaecrista* was used by K. H. Garren in his studies on ashy stem blight of beans (1). He found that it attacked beans, and formed the typical pycnidia and spores of *Macrophomina* on the dead bean tissue, thus leaving no doubt of the identity of the organism.

Pathogenicity of Macrophomina

To determine the pathogenicity of this fungus on *Chamaecrista procumbens*, several inoculation experiments were conducted, the seed being supplied by the Soil Conservation Service at Thorsby, Alabama. Seed were immersed for 20 minutes in concentrated, commercial sulphuric acid and then washed in running water for one hour. This treatment served to scarify the seeds and to disinfect their surfaces. The soil, in 6-inch pots, was autoclaved for 3 hours at 25 pounds' pressure, and then held in the greenhouse. After an inch or so of the top soil had been removed from each pot, about 25 seeds were placed on the surface and then covered thinly with part of the soil that had been removed. About 2 tablespoons of inoculum, consisting of sterilized oats on which the fungus was growing, was next placed over the surface of the soil in each pot and the remainder of the soil added. Controls were prepared in the same manner except that sterile oats were used instead of inoculum. The seeds were planted and inoculum was added Nov. 26, 1941, and the final notes were taken Feb. 17, 1942.

Only half as many seedlings appeared in the inoculated as in the control pots because of preemergence decay. The control plants remained healthy, grew to maturity, and set some seed. Some of the seedlings in the inoculated pots were dwarfed very early; others died and pycnidia were formed on the stems just above the soil. Many had very scant fibrous root systems and were dwarfed but lived to maturity. A few plants had pycnidia on the stems when the experiment was discontinued. Isolations were made from several plants and the roots of the remainder were placed in water. The fungus was recovered from each plant from which isolations were made and pycnidia were formed along the base of the stems of the plants placed in water. Hence, all plants in the infested soil contained the fungus. Isolations were made from a number of seeds produced on diseased plants, but the

fungus was never recovered. It is possible, however, that the seed coats were so hard that the fungus could not grow through them.

On July 7, 1942, another experiment was set up in the same manner, except that the fungus used was a reisolate from the previous experiment. In this test there was considerable preemergence decay. Some seedlings died soon after emerging and others grew to be an inch or two tall before they succumbed. Infection seemed to take place at almost any point on the hypocotyl (Fig. 2), the cotyledons, the plumule, or the young roots. As soon

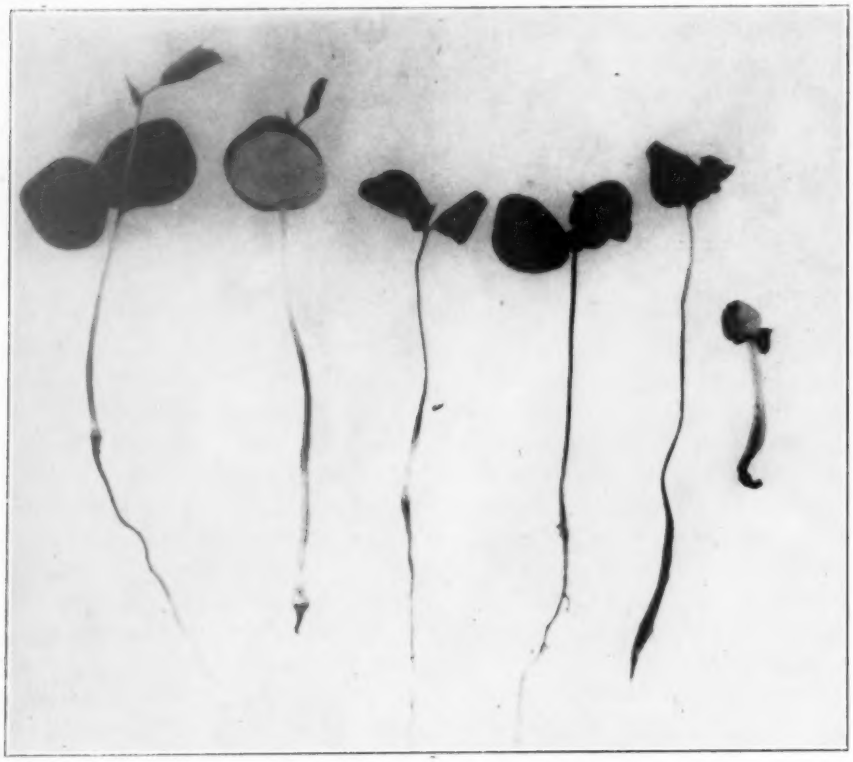

FIG. 2. Seedlings grown in the greenhouse in artificially infested soil. Plant at the left is nearly normal size and has only a slight superficial canker on the hypocotyl near the surface of the soil. The second plant from the left has a slightly deeper lesion at about the same place. The third, fourth, and fifth plants have their hypocotyls almost entirely involved and nearly severed. The hypocotyl of the plant at the extreme right was decayed early and the seedling remained dwarfed. ×1½.

as plants were 2 to 3 inches tall, however, they seemed to become resistant to this seedling decay and generally reached maturity. Some plants affected in the seedling stage, but not killed, grew to maturity, whereas the others died before maturity. When the plants approached maturity and had become greatly weakened or had died, many pycnidia appeared on the stems, usually at the base first but often higher, even on the branches. This raised the question as to whether these plants had not become infected until they were nearly dead, or had been infected in the early stages of growth but had not been injured appreciably.

In the hope of obtaining some information on this point, isolations were made from a number of plants that had passed the seedling stage, some being as tall as 12 inches but with little or no evidence of infection, to determine if they were invaded but not injured by the fungus. Some plants selected for this test wilted slightly at times, others were somewhat dwarfed, and still others appeared to be healthy. The plants were disinfected with calcium hypochlorite or alcohol and mercuric chloride, 1–1000, and ½-inch segments were planted on agar in plates. Segments were numbered from the root upwards so that it could be determined how far up the stem the fungus had grown. Sometimes alternate segments were planted. In one experiment 10 plants were used and the fungus was recovered from all, being isolated from the roots of 4 plants and from the stem just above the ground of the other 6. In another experiment the fungus was recovered from 4 of 6 plants. It was isolated from the roots of 3 and from the stem of the fourth plant about 2 inches above ground. In a third experiment the fungus was recovered from the root or crown tissue of 9 of 15 plants. It was obtained from the first above-ground segment as well as from the roots of 6 plants and from all the segments up to 3 inches above ground of one plant.

Forty-two plants growing in infested soil in one experiment grew to maturity and after dying they were examined for the presence of the fungus. Pycnidia were found on the stems of 36 plants and sclerotia were present under the epidermis of the other 6.

ANTHRACNOSE

In the autumn of 1942, plants of *Chamaecrista procumbens* growing under very dry conditions on uncultivated ground at Experiment, Georgia, were attacked by a fungus that killed the ends of the branches for a distance of 2 to 4 inches. The ends of affected twigs, with the brown dead leaves still attached, had fallen over to form a Shepherd's crook near the junction of the dead and live tissue (Fig. 3, A).

Isolation of the Pathogen

Some of the dead stems were held in a moist chamber for 48 hours at which time many salmon-colored spore masses were present on the dead tissue. By touching a sterile needle to the mass of spores and transferring those that adhered to it to a tube of sterile water and then plating loops of this spore suspension, it was possible to get a pure culture of the fungus.

Cultural and microscopic studies of the fungus isolated from the diseased plants have shown no consistent morphological difference between this pathogen and the conidial stage of *Glomerella cingulata* (Ston.) Spauld. and Schrenk from apple. Fifty spores from culture measured 4.5–6 × 10–17 μ (Av. 5.2 × 13.9 μ) which is close to the spore measurements given by Shear and Wood (5). An attempt to infect apple with the fungus obtained from *Chamaecrista* failed. Apples inoculated with the fungus isolated from apple were decayed. Nevertheless, in the absence of any morphological difference

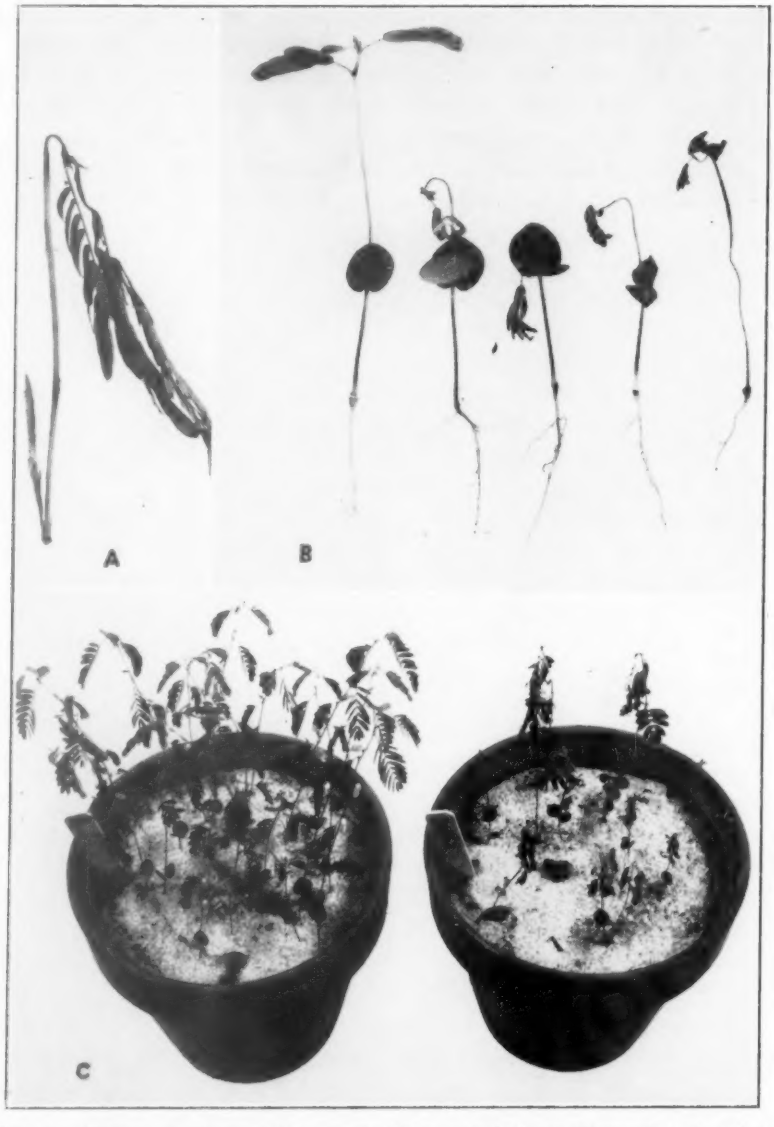

FIG. 3. Plants of *Chamaecrista procumbens* attacked by *Glomerella cingulata*. A. Naturally infected twig. Petiole and adjacent stem were killed and the weight of the leaf has bent the weakened stem into a shepherd's crook. ×1½. B. Control plant at the left. The other plants show varying degrees of injury to the stem above the cotyledons. The leaves of the affected plants have collapsed. The two plants at the right have more extensive injury and the stems below the cotyledons have become involved, the cotyledons have shriveled, and in case of the plant at the extreme right, have fallen. Photographed 5 days after inoculation. ×1½. C. Two pots of older plants, controls at the left and at the right infected plants with collapsed terminal shoots. Photographed 6 days after inoculation. ×$\frac{3}{10}$.

sufficient to differentiate it from the strain of *G. cingulata* from apple, this fungus from *Chamaecrista* is considered to be a strain of that species.

Pathogenicity of Glomerella Isolates

In the first inoculation experiment 4 pots of seedlings about 2 inches tall growing in sterilized soil in the greenhouse were used. The seed had been scarified and sterilized with sulphuric acid. A heavy suspension of spores was made by adding sterile water to an oat-agar slant on which the fungus was sporulating abundantly. Two pots of plants were atomized with the spore suspension and then placed in a moist chamber with 2 other pots atomized with sterile water as controls. The inoculations were made Nov. 11, 1942, and the pots were left in the moist chamber for 48 hours. There was no evidence of infection at the end of 48 hours, but in 96 hours the inoculated plants showed distinct injury. The petioles were dying and the leaflets wilting. In another day many of the leaflets were dry, the petioles were dead, and some of the cotyledons and stems were decidedly injured. All 15 plants inoculated were diseased, some being entirely dead above ground, others having their leaflets and cotyledons killed but the stem below the cotyledons still alive, and still others having the stem and cotyledons alive but the petioles and leaflets dead. The petioles usually were killed first and the fungus grew from these into the stem which sometimes was killed back only a short distance and at other times to the ground or lower. In general, the cotyledons remained free of infection, but often died as a result of the death of the stem. The appearance of some of the plants 5 days after being inoculated is illustrated (Fig. 3, B). On Nov. 17, 1942, 6 days after the inoculations, all seedlings in one pot and 9 in the other were dead. Of the 6 remaining plants in the second pot, all parts above the cotyledons were dead. All control plants remained healthy. The fungus was readily recovered from the dead seedlings. One week after the inoculations, 5 inoculated plants, whose stems had not been killed down as far as the cotyledons, were still alive. These plants were forming new buds and stems in the axils of the cotyledons. The plants were considerably retarded, however, and never grew as rapidly as the controls. It seems probable that had the pots been held in the moist chamber another 24 hours none of the plants would have survived.

This experiment shows that under high humidity seedlings of *Chamaecrista procumbens* are very susceptible to *Glomerella cingulata*. A reisolate of the fungus was used in other experiments and it also was very pathogenic to seedlings.

Having demonstrated that seedlings are very susceptible, older plants were inoculated to test their susceptibility. In one experiment 3 pots of plants 4 to 5 inches tall were used, the plants in 2 of the pots being inoculated Nov. 24, 1942, and those in the third being held as controls. Four days later all the inoculated plants showed some injury. The petioles were killed just as in seedlings. The stems at the base of the leaf stalks were injured in some cases and the fungus was fruiting abundantly on the dead petioles and stems. A large proportion of the leaflets on plants with 2 leaves were dead, but when there were 3 or more leaves those below the second were still

alive. The controls had 4 to 7 leaves at this time and all were healthy (Fig. 3, C). The fungus seemed to make little further progress and since it was thought that this might be due to the dry atmosphere of the greenhouse, one pot of plants was returned to the moist chamber for 24 hours. No appreciable change took place. On Dec. 9, 1942, one pot had 10 plants with the tops nearly dead; 5 of the plants each had one leaf alive and only the cotyledons remained on the other 5. These plants were so weakened that even though they did not die they always remained greatly stunted. In one instance a new shoot was being formed in the axil of a cotyledon.

Thus, severe injury and often death may result from the disease, even when plants 4 to 5 inches tall are attacked. In another experiment, still older plants were used. These plants were green but vegetative growth had ceased and nearly mature pods were present. No infection was obtained. The results of this experiment confirm previous observations that only actively growing tissue is susceptible, at least under the conditions under which the disease has been studied.

Seedlings of *Chamaecrista fasciculata* were inoculated at the same time with the same inoculum and were held in the same moist chamber as the mature plants just discussed. Abundant infection was obtained. This demonstrated that the inoculum and the environmental conditions were suitable for infection and also that *C. fasciculata* probably is as susceptible to this fungus as is *C. procumbens*.

DISCUSSION

Chamaecrista procumbens, especially in the seedling stage, is very susceptible to *Macrophomina phaseoli*, just as are many other legumes as well as a wide variety of non-leguminous plants (2, 3, 4). Plants infected in the seedling stage, but not killed, may die later or may grow to maturity. In some experiments the plants appeared to become resistant to infection when they were 3 to 4 inches tall. However, these experiments were in the greenhouse with plants growing in pots that dried out at times. This deficiency of water at irregular intervals may have resulted in a more rapid hardening of the stems, thus slowing down or preventing infection, than would have existed in plants of the same age under field conditions. Possibly the drying may affect the pathogenicity of the fungus as well as the resistance of the host. It is known that the pathogenicity of the fungus on the same host is quite variable in different localities. For example, Garren (1) pointed out that in 1941 at Experiment, Georgia, ashy stem blight and southern blight together accounted for less than 5 per cent of the recorded dead bean plants, whereas at Tifton, Georgia, ashy stem blight alone was responsible for 60 per cent of the dead plants. Investigators working on this disease of beans at the Georgia Agricultural Experiment Station have informed the writer that ashy stem blight is always much more destructive at Tifton than at Experiment. The precise cause of the variation in destructiveness of this parasite is unknown, but it is thought to be some environmental factor, probably tem-

perature or moisture, or both (2, 4, 6). It is quite possible that the *Macrophomina* root rot of *Chamaecrista procumbens* may be much more severe in the field at Thorsby, Alabama, or elsewhere, than in the greenhouse at Experiment. This appeared to be the case.

An anthracnose caused by *Glomerella cingulata* was found damaging the terminal shoots of *Chamaecrista procumbens*. Experiments proved that this fungus is very pathogenic on seedlings and on vigorously growing parts of older plants under conditions suitable for infection.

It seems probable, therefore, that either anthracnose or root rot, or both, may cause considerable loss of young plants of *Chamaecrista procumbens* under environmental conditions suitable for the rapid spread and development of the fungi, conditions such as often exist during prolonged wet periods accompanied by high temperatures in late spring or early summer. Considerable damage may be caused by the anthracnose fungus to *C. fasciculata* also.

SUMMARY

Two diseases of *Chamaecrista* have been described, a root rot and an anthracnose caused by *Macrophomina phaseoli* and *Glomerella cingulata*, respectively. So far as known, the former fungus attacks *C. procumbens* only, but the latter is destructive both to this species and to *C. fasciculata*. The root-rot fungus was more pathogenic on young plants under the experimental conditions, but observations indicated that older plants can be killed. The anthracnose fungus can kill seedlings in a few days; only the actively growing ends of the branches of older plants are susceptible, and mature plants are highly resistant.

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Pages 10 and 11, table 1, *read Milium for Millium* and *Puccinellia for Puccinielia*

Page 13, last line, *read vulgare for vulare*

Page 17, paragraph 2, line 13, *read* grass *for* gross

Page 18, paragraph 4, *read Milium for Millium*

Page 71, line 10, *read* from below the tip *for* from the tip

Page 137, paragraph 2, lines 11 and 12, *read* 10 per cent copper and 90 per cent sulphur *for* 70 per cent copper and 30 per cent sulphur

Page 249, line following footnote 6 should follow line 5 of text

Page 335, in title, in paragraph 1, line 2, and in paragraph 3, line 1, *read Levisticum officinale for Ligusticum scoticum*

Page 340, paragraph 2, line 1, *read Levisticum officinale for Ligusticum scoticum*

Pages 359 and 362. The legend under map on page 359 belongs to diagram on page 362 and the legend under diagram on page 362 belongs to map on page 359

Page 372, line 3, *read* 2 L *for* 1.4 L

Page 402, line 20, *read* materials not eliminated *for* materials eliminated

Page 509, last line, *read* propiono *for* propriono

Page 583, line 4, *read* 4576–1 *for* 4567–1

Page 606, line 1, *read Daucus carota for Daucus carotae*

Page 628, paragraph 3, line 3, and page 630, paragraph 3, line 9: *after* no menace (page 628) and *after* when planted (page 630) *add* aside from the possibility of introducing the fungus into the soil

Page 727, line 16, *read sprengeri for sprengleri*

Page 773, transpose diagrams of figures 1 and 2

Page 950, line 6, *read* Oestland *for* Pestlund

Page 990, paragraph 3, *read* W. J. Zaumeyer, President; H. B. Humphrey, Vice-President; *for* H. B. Humphrey, President; W. J. Zaumeyer, Vice-President

Page 992, *read* C. L. LEFEBVRE, *for* C. L. LEFABVRE

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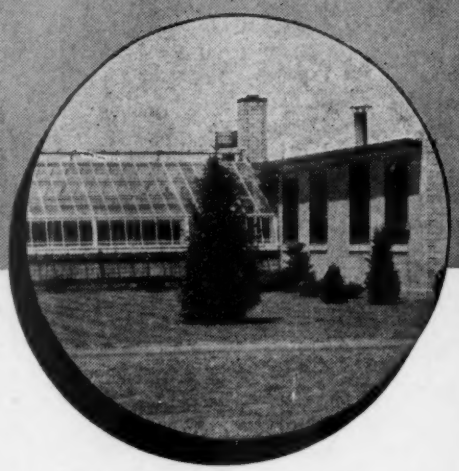

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